FINAL

Intrinsic Remediation
Treatability Sudy for Site FT01

King Salmon Airport
Alaska

Prepared For

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base, Texas
San Antonio, Texas

and

Ellmendorf Air Force Base
Anchorage, Alaska

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24 September 1999

Mr. Jerry Hansen
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Subject: Submittal of the Final Treatability Study in Support of Intrinsic Remediation for Fire Training Area 1 (FT01), King Salmon Airport, Alaska (Contract F41624-92-D-8036-0006)

Dear Mr. Hansen:

Enclosed please find two copies of the September 1999 Final Treatability Study (TS) in Support of Intrinsic Remediation for Fire Training Area 1 (FT01), King Salmon Airport, Alaska. This report was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) and Elmendorf Air Force Base (AFB).

The intent of the TS was to determine the role of natural attenuation in remediating fuel contamination in groundwater at the FT01 site. The draft TS was submitted to AFCEE in May 1996. Comments on the draft report were received from AFCEE as reviewed by Mr. Jon Atkinson of AFCEE dated December 16, 1996. Responses to these comments were prepared by Parsons ES and are attached in Appendix G.

In addition, groundwater sample data collected by the US Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRMRL) in September 1998 has been evaluated and incorporated into this Final TS as an addendum (Appendix H) under Air Mobility Command (AMC) Contract F11623-94-D0024-RL71. Conclusions from the addendum were further included in the Final TS Executive Summary.

If you have any questions or comments regarding this package, please do not hesitate to contact me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

Bruce M Henry

Bruce M. Henry, P.G.
Project Manager

Enclosures
c.c. Mr. Don Kampbell – USEPA NRMRL (two copies)
Mr. Jonathon Decker – Parsons ES (w/o enclosure)

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FINAL

TREATABILITY STUDY IN SUPPORT OF INTRINSIC REMEDIATION FOR FIRE TRAINING AREA 1 (FT01)

at

KING SALMON AIRPORT
KING SALMON, ALASKA

September 1999

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

AND

ELMENDORF AIR FORCE BASE
ANCHORAGE, ALASKA

Prepared by:

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EXECUTIVE SUMMARY

This report presents the results of a treatability study (TS) performed by Parsons Engineering Science, Inc. (Parsons ES) in the vicinity of Site FT01 at King Salmon Airport in King Salmon, Alaska to evaluate the use of intrinsic remediation with long-term monitoring (LTM) as a remedial option for dissolved benzene, toluene, ethylbenzene, and xylene (BTEX) contamination in the shallow groundwater. Soil and groundwater contamination in the form of BTEX and trichloroethene (TCE) also was identified at the former radar approach control (RAPCON) site (southwest of Site FT01) during site characterization activities performed as part of this TS. Therefore, the RAPCON site was included as part of this TS, and dissolved TCE contamination was considered during the selection of remedial alternatives. Soil, groundwater, and surface water contamination associated with Site FT01 and the RAPCON site are collectively referred to as the "study area". This TS focused on the impact of dissolved BTEX and TCE on the shallow groundwater system at the study area and on a downgradient surface water body, Red Fox Creek. Site history and the results of soil and groundwater investigations conducted previously also are summarized in this report.

A review of BTEX and TCE isopleth maps for the study area confirm that BTEX- and TCE-contaminated groundwater are discharging to Red Fox Creek. The BTEX and TCE isopleth maps also indicate that the majority of groundwater contamination discharging to Red Fox Creek is emanating from an unidentified source area at the RAPCON site. Comparison of BTEX, electron acceptor, and biodegradation byproduct isopleth maps for the study area provides strong qualitative evidence of the biodegradation of BTEX compounds at Site FT01 and the RAPCON site. Geochemical data suggest that biodegradation of fuel hydrocarbons is occurring via aerobic respiration and the anaerobic processes of denitrification and iron reduction. Strongly reducing groundwater conditions were not present at the RAPCON site, which may be inhibiting the potential reductive dechlorination of TCE. This is supported by the absence of sequential daughter products produced from the reductive dechlorination of TCE (e.g., dichloroethene, vinyl chloride, and ethene) at the study area. However, elevated BTEX concentrations commingled with TCE at the RAPCON site suggest that cometabolism may be a potential TCE degradation mechanism.

An important component of this study was an assessment of the potential for BTEX contamination in groundwater to migrate from the source areas to potential receptor exposure points. In particular, this component focused on the contaminant mass loading resulting from the discharge of BTEX-contaminated groundwater into Red Fox Creek, approximately 800 and 200 feet southwest of Site FT01 and the RAPCON site, respectively. To help estimate mass loading rates, the Bioplume II numerical model was used to estimate the rate and direction of dissolved BTEX movement through the shallow groundwater under the influence of advection, dispersion, sorption, and biodegradation. Modeling the fate and transport of TCE contamination at the study area was not within the scope of this TS. Input parameters for the Bioplume II groundwater flow and solute transport model were obtained from available site characterization data, supplemented with data collected by Parsons ES. Model parameters that were not measured at the site were estimated using reasonable literature values.

The results of this study suggest that sorption, dispersion, and biodegradation are attenuating dissolved BTEX at Site FT01 before migration and discharge to Red Fox Creek. However, natural attenuation is insufficient to prevent continued discharge of contaminated groundwater to Red Fox Creek from the RAPCON site in the near future. Red Fox Creek flows throughout most of the year, which is significant in attenuating groundwater contamination discharging to the creek by the processes of dilution and volatilization. Despite contaminant losses through dilution and volatilization, contaminant concentrations in Red Fox Creek are currently above state water quality standards for total aromatic hydrocarbons (total BTEX). In addition, available ecological risk assessment data suggest a hydrocarbon bioaccumulation hazard to aquatic species indigenous to Red Fox Creek. TCE also discharges to Red Fox Creek and may exceed the state water quality standard (surface water TCE concentrations were not measured).

The current RAPCON site impact on Red Fox Creek requires that more aggressive measures be taken to remediate the study area than reliance on intrinsic remediation alone. Therefore, the Air Force recommends that the implementation of a remediation strategy that includes a characterization of the RAPCON source area, excavation of source soils at the RAPCON site with treatment at a nearby bioventing landfarm, biosparging, intrinsic remediation, LTM, and institutional controls in order to reduce risk to human health and the environment and rapidly achieve state regulatory standards (remedial Alternative 3). Institutional controls such as restrictions on shallow groundwater use, access to the study area, and access and use of the impacted segment of the creek would limit completion of receptor exposure pathways while site remediation was in progress.

Groundwater sampling performed at Site FT01 in September 1996 and September 1998 (see the addendum to this TS in Appendix H) indicate that BTEX concentrations in monitoring wells near the source area (ESMW-1A and MW-95) decreased significantly between 1995 and 1998. However, BTEX concentrations at downgradient location ESMW-5A, along the approximate axis of the plume, increased significantly. The decrease in source area BTEX concentrations and a simultaneous increase in downgradient BTEX concentrations from 1995 to 1998 is possibly the result of altered leaching conditions during source area excavation in 1995. Peripheral LNAPL sources may have been disturbed and remobilized at the groundwater interface during source excavation. This may have resulted in a temporary increase in leaching rates, thereby causing a slug of BTEX contamination to migrate from the source area. As the groundwater BTEX slug migrates, disperses, and degrades along the plume axis, the plume should stabilize in a steady-state configuration. Geochemical data collected in 1996 and 1998 strongly suggest that biodegradation of fuel hydrocarbons continues at the site via aerobic respiration, denitrification, and iron reduction. The observed 1998 BTEX plume at Site FT01 could not be compared to that predicted by the Bioplume II model presented in this TS, because the downgradient extent of the September 1998 BTEX plume was not delineated.

To verify the Bioplume II model predictions, and to ensure that the selected technologies are meeting remediation objectives, the Air Force recommends using 14 LTM wells to monitor the long-term migration and degradation of the dissolved BTEX plume at Site FT01 and the dissolved BTEX and TCE plumes at the RAPCON site. In addition, four surface water stations along Red Fox Creek should be monitored to assess the impact of groundwater discharging into the surface water. In conjunction with

engineered source removal at the RAPCON site, the study area should be sampled annually for 20 years, with the need for additional sampling and the appropriate sampling interval reevaluated at that time. Specifically, LTM sampling at Site FT01 will continue until the predicted remediation of the groundwater plume in 12 years (by 2007). LTM sampling will continue at the RAPCON site for the remainder of LTM (until 2015). Furthermore, if the plumes at either site are observed to stabilize, recede, or disappear on the basis of LTM data, the frequency of sampling may be reduced to every other year or eliminated, as appropriate. In addition to analyses used to verify the effectiveness of intrinsic remediation, the groundwater and surface water samples should be analyzed for BTEX and chlorinated solvents by US Environmental Protection Agency Method SW8260. If data collected under the LTM program indicate that the implemented remedial alternative is not sufficient to reduce BTEX and TCE concentrations at Red Fox Creek to levels considered protective of human health and the environment, additional engineered controls to augment the beneficial effects of intrinsic remediation and the implemented engineered remediation systems may be necessary.

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LIST ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
µg/kg	micrograms per kilogam
µg/L	micrograms per liter
2-D	two-dimensional
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
ASCII	American Standard Code for Information Interchange
AST	aboveground storage tank
atm-m^3/mol	atmosphere-cubic meters per mole
AWWA	American Water Works Association
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CEOS	Civil Engineering Operations Squadron
cy	cubic yards
DCA	dichloroethane
DCE	dichloroethene
DO	dissolved oxygen
DROs	diesel-range organics
EMCON	EMCON Alaska, Inc.
ES	Engineering-Science, Inc.
Fe^{2+}	ferrous iron
Fe^{3+}	ferric iron hydroxide
ft/ft	foot per foot
ft/min	feet per minute
ft/year	feet per year
ft^3/day	cubic feet per day
ft^3/ft^3/day	cubic feet per cubic feet per day
ft^3/sec	cubic feet per second
g/cc	grams per cubic centimeter
GAC	granular activated carbon
GRO	gasoline-range organics
HDPE	high-density polyethylene tubing
HSA	hollow-stem auger
ID	inside diameter
IRP	Installation Restoration Program
K_{oc}	soil sorption coefficient
KSA	King Salmon Airport
LNAPL	light nonaqueous-phase liquid
LTM	long-term monitoring
MEK	methyl ethyl ketone
mg/kg	milligrams per kilogram
mllw	mean lower low water
mmHg	millimeters of mercury
Mn^{2+}	soluble manganese
MOC	Method of Characteristics
mV	millivolts

N	nitrogen
NO^3	nitrate ion
NORAD	North American Air Defense
NRMRL	National Risk Management Research Laboratory
OSWER	Office of Solid Waste and Emergency Response
Parsons ES	Parsons Engineering Science, Inc.
PCE	tetrachloroethene
PID	photoionization detector
POC	point of compliance
ppbv	parts per billion by volume
PVC	polyvinyl chloride
QC	quality control
R	coefficient of retardation
r^2	coefficient of determination
RAOs	remedial action objectives
RAPCON	radar approach control
redox	reduction oxidation
RI/FS	Remedial Investigation/Feasibility Study
RMS	root mean squared
RSKERL	Robert S. Kerr Environmental Research Laboratory
SAIC	Science Applications International Corporation
SAP	Sampling and Analysis Plan
SVOCs	semivolatile organic compounds
TCA	1,1,1-trichloroethane
TCB	1,2,4-trichlorobenzene
TCE	trichloroethene
TEMB	tetramethylbenzene
TMB	trimethylbenzene
TOC	total organic carbon
TPH	total petroleum hydrocarbon
TS	Treatability Study
USAF	United States Air Force
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
UST	underground storage tank
VC	vinyl chloride
VOCs	volatile organic compounds

SECTION 1

INTRODUCTION

This report was prepared by Parsons Engineering Science, Inc. (Parsons ES) and presents the results of a treatability study (TS) conducted to evaluate the use of intrinsic remediation for remediation of groundwater contaminated by petroleum hydrocarbons released during fire training operations at Fire Training Area 1 (FT01), King Salmon Airport (KSA) [formerly King Salmon Air Force Base (AFB), or the Base], King Salmon, Alaska. The former radar approach control (RAPCON) site located southwest of Site FT01 is also addressed in this TS. As used throughout this report, the term "intrinsic remediation" refers to a management strategy that relies on natural attenuation mechanisms to control exposure of receptors to concentrations of contaminants in the subsurface that exceed regulatory levels intended to be protective of human health and the environment. "Natural attenuation" refers to natural biological, physical, and chemical processes that facilitate intrinsic remediation.

Intrinsic remediation is an innovative remedial approach that relies on natural attenuation to remediate fuel contaminants dissolved in groundwater. Mechanisms for natural attenuation of fuel hydrocarbons include advection, dispersion, dilution from recharge, sorption, volatilization, and biodegradation. Of these processes, biodegradation is the only mechanism working to transform contaminants into innocuous byproducts. Intrinsic bioremediation occurs when indigenous microorganisms work to bring about a reduction in the total mass of contamination in the subsurface without the addition of nutrients. Patterns and rates of intrinsic remediation can vary markedly from site to site depending on governing physical and chemical processes. The main emphasis of the work described herein was to evaluate the potential for naturally occurring biodegradation mechanisms to reduce dissolved fuel hydrocarbon concentrations in groundwater to concentrations below regulatory standards that are intended to be protective of human health and the environment. This study is not intended to be a contamination assessment report or a remedial action plan for FT01 and the RAPCON site; rather, it is provided for the use of the Base and its prime environmental contractor(s) as information to be used for future decision making regarding this site.

1.1 SCOPE AND OBJECTIVES

Parsons ES was retained by the United States Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division to conduct site characterization and groundwater modeling to evaluate the scientific defensibility of intrinsic remediation with long-term monitoring (LTM) as a remedial option for fuel-contaminated groundwater at Site FT01. Site characterization activities conducted in September 1994 and July 1995 consisted of numerous tasks that were required to fulfill the project objective. These tasks included:

- Reviewing existing hydrogeologic and soil and groundwater quality data for the site;
- Conducting supplemental site characterization activities to determine the nature and extent of soil and groundwater contamination and the groundwater flow conditions in the affected aquifer;
- Collecting geochemical data in support of intrinsic remediation;
- Developing a conceptual hydrogeologic model of the shallow saturated zone, including the current distribution of contaminants;
- Evaluating site-specific data to determine whether naturally occurring processes of contaminant attenuation and destruction are occurring in groundwater at the site;
- Designing and executing a Bioplume II groundwater flow and solute transport model for site hydrogeologic conditions;
- Simulating the fate and transport of fuel hydrocarbons in groundwater under the influence of advection, dispersion, adsorption, and biodegradation using the Bioplume II model;
- Evaluating a range of model input parameters to determine the sensitivity of the model to those parameters and to consider several contaminant fate and transport scenarios;
- Determining if naturally occurring processes are sufficiently eliminating discharge of contaminated groundwater to surface water and minimizing dissolved hydrocarbon plume expansion so that water quality standards can be met at a downgradient point of compliance (POC) or surface water body;
- Assessing potential exposure pathways for potential current and future receptors;
- Developing remedial action objectives (RAOs) and reviewing available remedial technologies;
- Using the results of modeling to recommend the most appropriate remedial option based on specific effectiveness, implementability, and cost criteria; and
- Providing a LTM plan that includes LTM and POC wells and a sampling and analysis plan (SAP).

Site characterization activities completed in September 1994 in support of intrinsic remediation included the collection of soil samples and placement of monitoring wells with a hollow-stem auger (HSA) drill rig; aquifer testing; static groundwater level measurement; groundwater sample collection from site monitoring wells; and analysis of groundwater and soil samples. Additional site characterization activities were performed in July 1995 to further delineate groundwater contamination and to measure trends in groundwater contaminant attenuation. The July 1995 site characterization effort involved the installation of temporary groundwater monitoring points, groundwater sample

collection from existing monitoring wells/points, surface water and sediment sample collection, and analysis of groundwater, surface water, and sediment samples. Furthermore, results of groundwater sampling performed in September 1996 by the United States Air Force (USAF), and in September 1998 by the United States Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRMRL) (Site FT01 only), were not available for analysis in preparation of this TS. Data for these sampling events has been analyzed in an addendum to this TS (Appendix H).

Site-specific data were used to develop a solute fate and transport model for the site using Bioplume II and to conduct a preliminary exposure pathways analysis. The modeling effort was used to predict the future extent and concentration of the dissolved contaminant plume by modeling the combined effects of advection, dispersion, sorption, and biodegradation. Results of the model were used to predict future discharge to surface water, to assess the potential for completion of other exposure pathways involving groundwater, and to determine whether intrinsic remediation with LTM is an appropriate and defensible remedial option for contaminated groundwater. The results will be used to provide technical support for the intrinsic remediation with LTM remedial option during regulatory negotiations, as appropriate.

Alternate remedial options were considered to identify the major advantages and disadvantages associated with different groundwater remedial strategies. Hydrogeologic and groundwater chemical data necessary to evaluate these remedial options were either collected under this program, or were available from previous site investigations, or from the technical literature. Field work conducted under this program, however, was oriented toward the collection of supplementary hydrogeologic and geochemical data necessary to document and model the effectiveness of intrinsic remediation with LTM for restoration of fuel-hydrocarbon-contaminated groundwater.

1.2 REPORT ORGANIZATION

This TS contains nine sections, including this introduction, and six appendices. Section 2 summarizes site characterization activities. Section 3 summarizes the physical characteristics of the study area. Section 4 describes the nature and extent of soil, groundwater, and surface water contamination, and the geochemistry of soil and groundwater at the site. Section 5 describes the Bioplume II model and design of the conceptual hydrogeologic model for the site; lists model assumptions and input parameters; and describes sensitivity analyses, model output, and the results of the Bioplume II modeling. Section 6 presents a comparative analysis of remedial alternatives. Section 7 presents the LTM plan for the site. Section 8 presents the conclusions of this work and provides recommendations for further work at the site. Section 9 lists the references used to develop this document. Appendix A contains borehole logs, monitoring well construction diagrams, slug test results, and survey data. Appendix B presents previous analytical and unpublished data used in the preparation of this report. Appendix C presents soil, sediment, groundwater, and surface water analytical results collected as part of this TS. Appendix D contains Bioplume II model input parameters and calculations related to model calibration. Appendix E contains Bioplume II model input and output in American Standard Code for Information Interchange (ASCII) format on a diskette. Appendix F contains calculations for remedial option design and costing. Appendix G includes Parsons ES responses to AFCEE

comments on the Draft TS, and Appendix H contains an addendum to this TS based on subsequent groundwater sampling in September 1996 and September 1998.

1.3 INSTALLATION DESCRIPTION AND HISTORY

KSA is situated on a 216-acre site located on the upper, northwestern side of the Alaskan Peninsula (Figure 1.1). Anchorage, Alaska is 280 miles to the northeast. KSA is located on the northern bank of the Naknek River (Figure 1.2). The closest communities are the small towns of King Salmon, located adjacent to the southern boundary of KSA, and Naknek and South Naknek, located approximately 13 miles west-northwest of KSA along the Naknek River. KSA is accessible only by air or water.

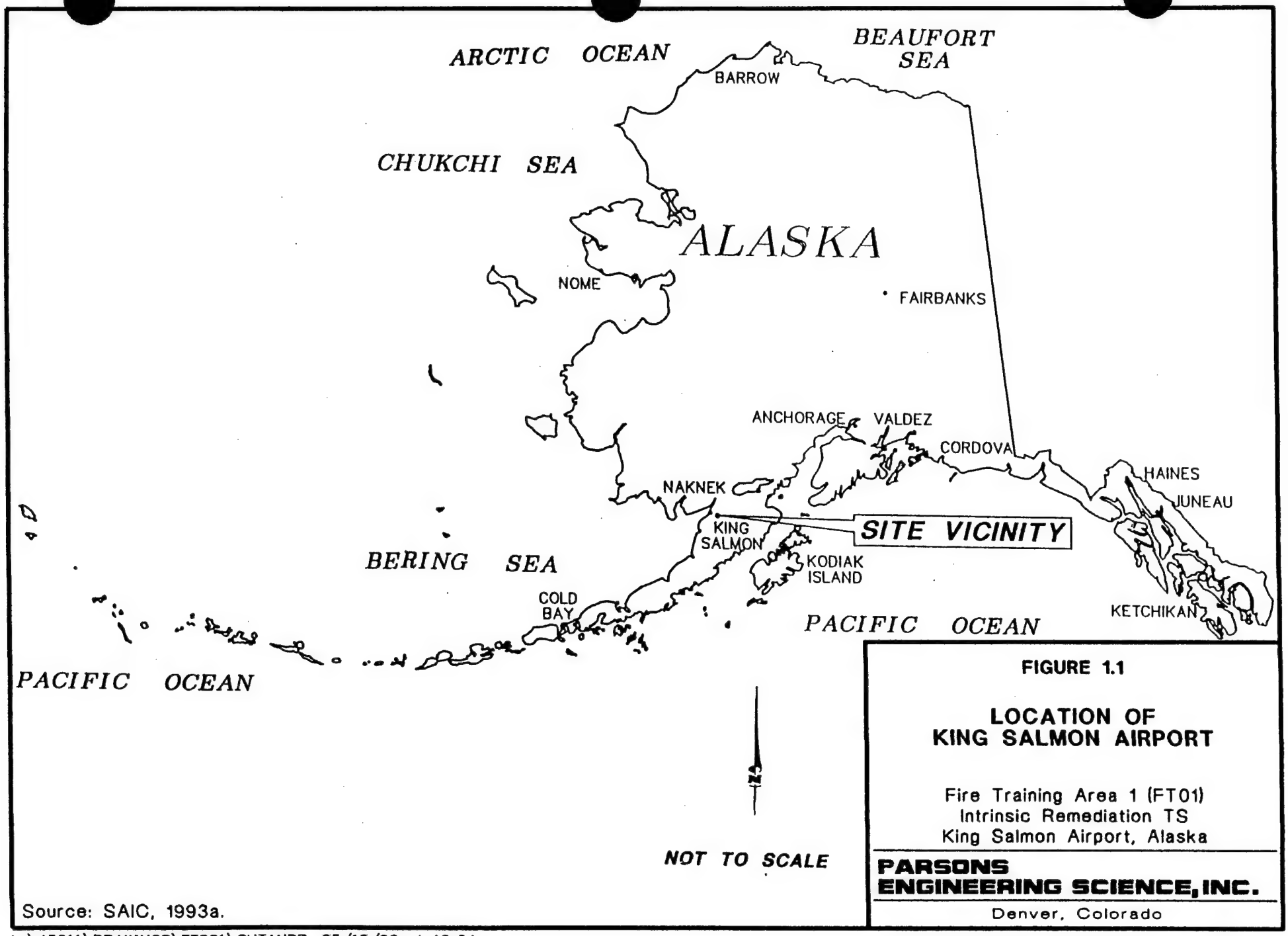
KSA was formerly a forward operating base that hosted the North American Aerospace Defense Command with a contingent of F-15 Eagles rotated from Elmendorf AFB. Maintenance and support for the F-15s at KSA was provided by the 643rd Support Squadron. This squadron was directed by the 3rd Control Wing out of Elmendorf AFB.

In addition to F-15s, KSA was a base used for long-range radar connected to the North American Defense (NORAD) Regional Operations Control Center at Elmendorf AFB.

1.4 SITE BACKGROUND

Site FT01 is located in the east-central portion of KSA, approximately 2,000 feet east/northeast of the intersection of the main runways. The fire training area was used from 1980 to 1992 for fire training exercises that involved the use of fuels, solvents, oils, and fire retardant chemicals [EMCON Alaska, Inc. (EMCON), 1994a]. The main feature of the area is an unlined, circular pit approximately 50 feet in diameter. This pit is accessible by an adjacent road leading to the airport and the pit is approximately 800 feet due north of and hydraulically upgradient from Red Fox Creek. Figure 1.3 shows the location of Site FT01 relative to KSA.

For the purposes of this TS, Site FT01 refers to the area including the former fire training area and the plume of fuel-hydrocarbon-contaminated groundwater extending southwest as far as Red Fox Creek. The RAPCON site southwest of FT01 is included in this area. Figure 1.4 is a site map showing the FT01 vicinity in detail. A Phase I records search performed under the Base installation restoration program (IRP) in 1985 identified the site as potentially contaminated [Engineering-Science, Inc. (ES), 1985]. Communications with airport personnel revealed that an aboveground storage tank (AST) was reportedly removed from the site on an undetermined date [Science Applications International Corporation (SAIC), 1993b]. Fuel and solvent storage prior to use in fire training activities, transfer of fuels and solvents to the fire training pit, and incomplete combustion of fuels and solvents during fire training exercises are the probable contaminant sources. Soil and groundwater fuel contamination at Site FT01 first was confirmed during an airport-wide preliminary RI/FS involving 11 sites, including Site FT01 (SAIC, 1993b). EMCON installed additional monitoring wells and collected additional soil and groundwater samples in October 1993 to supplement RI/FS field investigation results. Residual light nonaqueous-phase liquid (LNAPL) was detected in soil samples. These results suggested possible groundwater plume migration to Red Fox Creek.



Source: SAIC, 1993a.

FIGURE 1.1

LOCATION OF KING SALMON AIRPORT

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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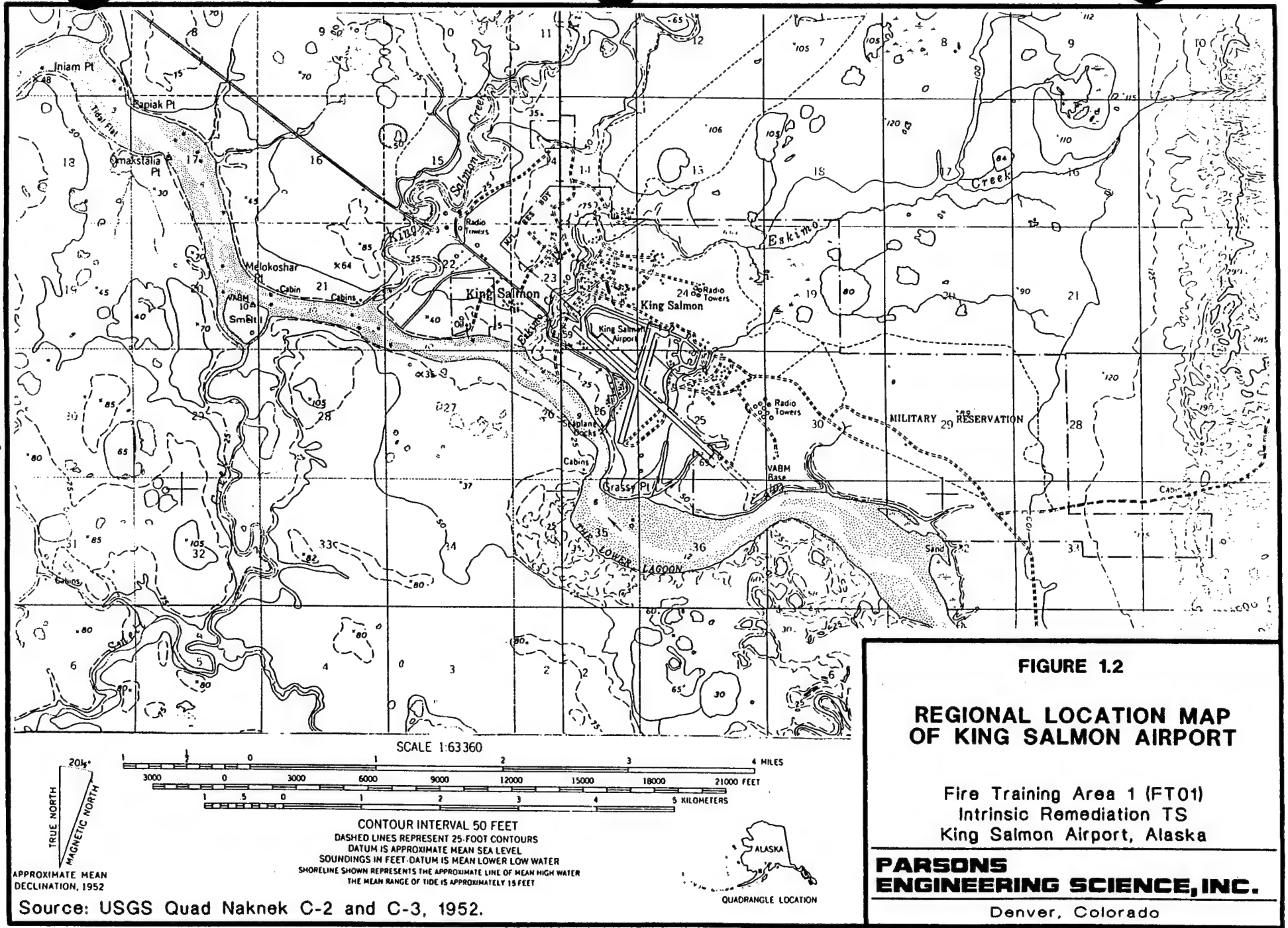

Source: USGS Quad Naknek C-2 and C-3, 1952.

FIGURE 1.2

REGIONAL LOCATION MAP OF KING SALMON AIRPORT

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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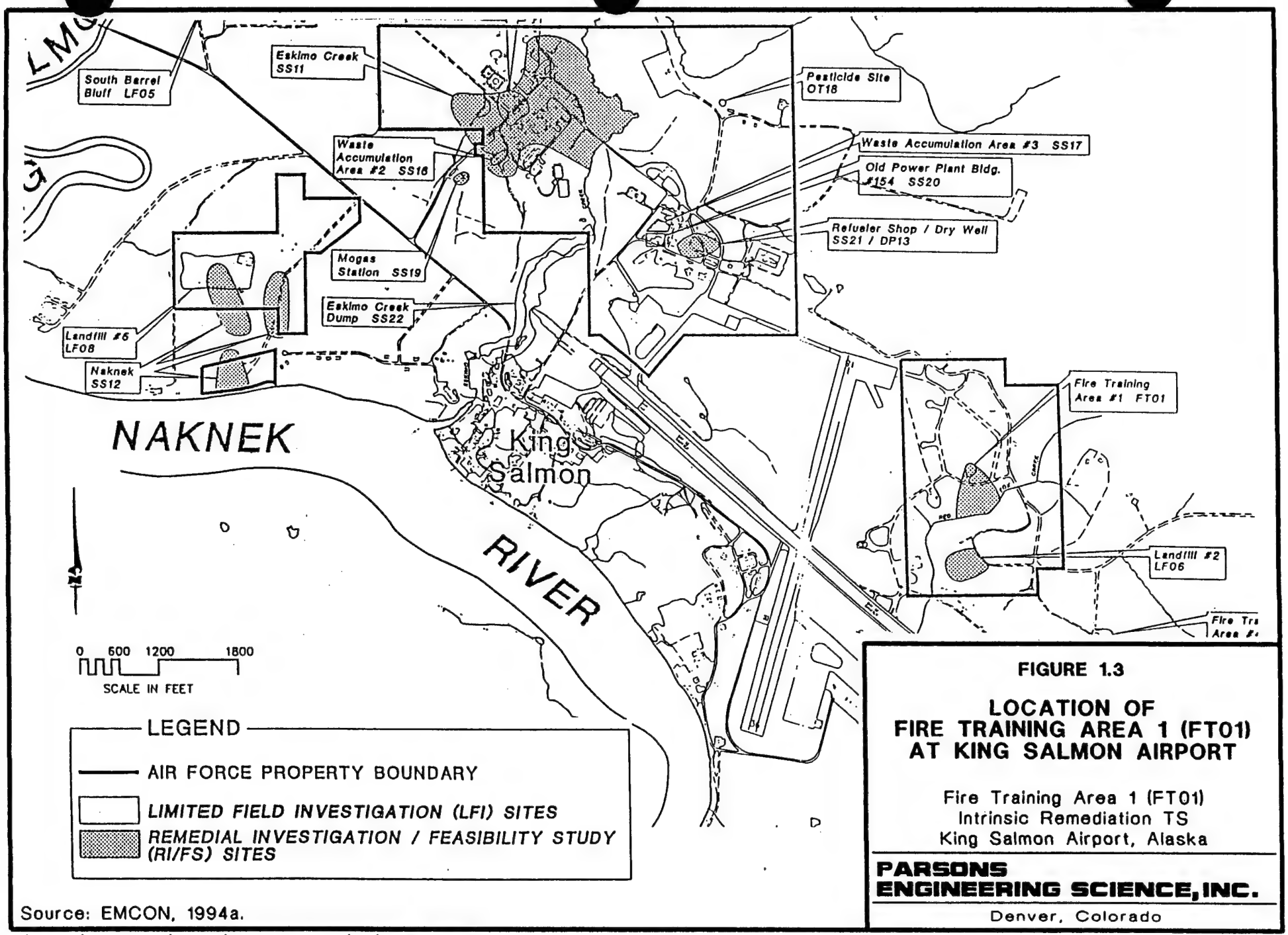

Source: EMCON, 1994a.

FIGURE 1.3

LOCATION OF FIRE TRAINING AREA 1 (FT01) AT KING SALMON AIRPORT

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

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Denver, Colorado

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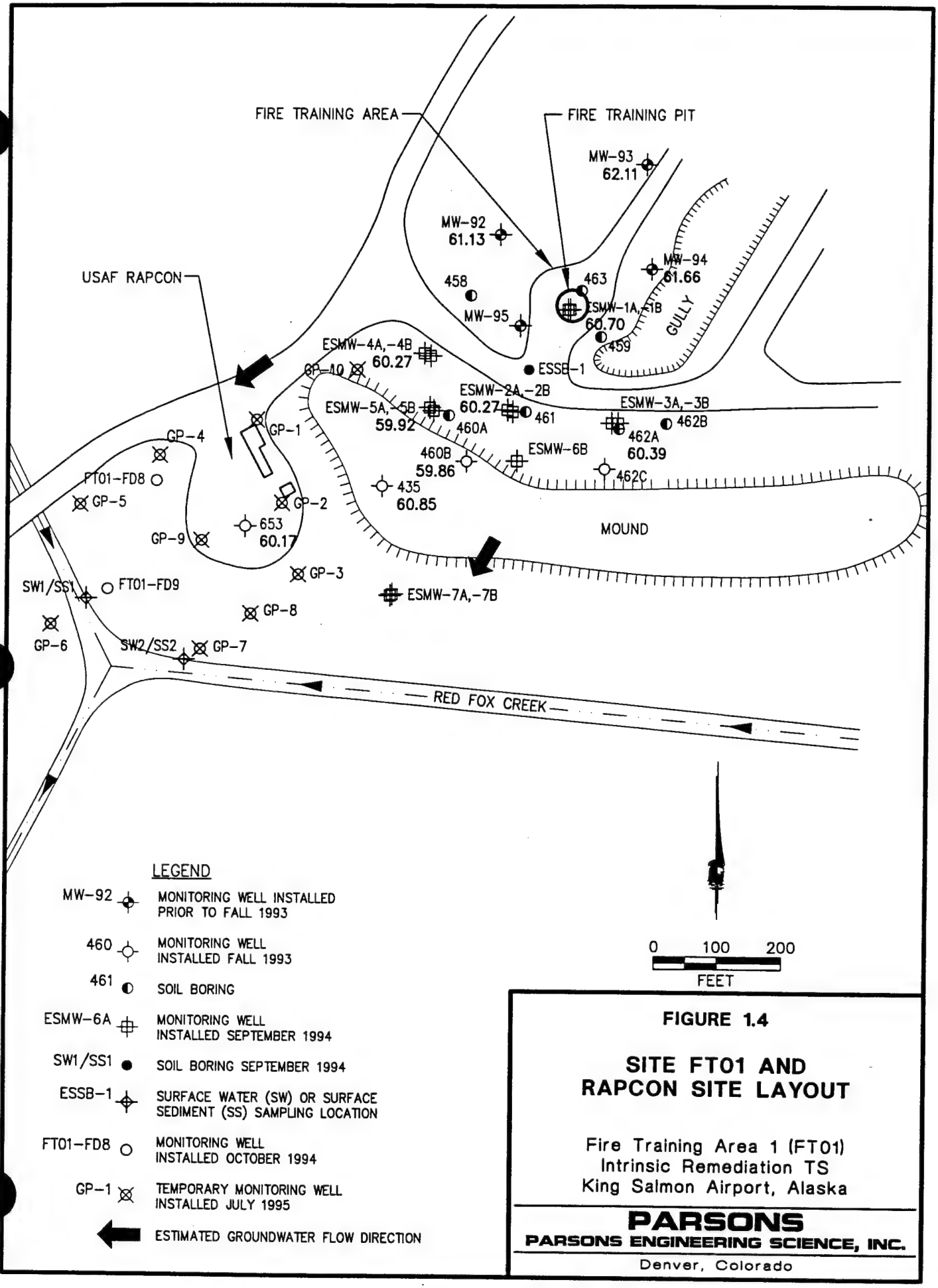

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FIGURE 1.4

SITE FT01 AND RAPCON SITE LAYOUT

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

Data collected during site investigations after 1993 (including data collected as part of this TS) suggest elevated fuel hydrocarbon and TCE concentrations in the vicinity of the RAPCON site to the southwest of the fire training pit. These contaminant concentrations are likely a result of an unidentified spill area at the RAPCON site, which was not identified as a site of concern under the Base IRP. Unconfirmed information suggests that a former 500-gallon UST associated with a demolished building (possibly building 560) was located at the RAPCON site (Environmental Management, Inc., 1996). Furthermore, a 2,000 gallon AST with unknown contents was reportedly removed at an unknown date (SAIC, 1993b). These previous tanks are the probable source of soil and groundwater contamination at the RAPCON site. The RAPCON site was included under the scope of this TS because groundwater contamination from Site FT01 potentially commingles with groundwater contamination from the RAPCON site. Site FT01 and the RAPCON site are collectively referred to as the "study area" in this report.

Approximately 2,025 cubic yards (cy) of contaminated soil was excavated and removed from Site FT01 between June 27 and August 1, 1995 (EMCON, 1996a). This action effectively removed all petroleum-impacted soils from the vadose zone (EMCON, 1996a). Numerous reports are available for the study area that summarize data collected from different field characterization efforts, including:

- *Installation Restoration Program, King Salmon Airport, Phase 1: Records Search* (ES, 1985);
- *Installation Restoration Plan, King Salmon Airport, Stage 1, Final Technical Report* (CH2M Hill, 1989);

Installation Restoration Plan, Stage 2, Final Draft Technical Report (CH2M Hill, 1990);

- *Report of Ground Water Monitoring Well Sampling and Analysis, King Salmon Airport, Alaska* (SAIC, 1992);
- *Ground Water Monitoring Performed October 1992, King Salmon Airport, King Salmon, Alaska* (SAIC, 1993a);
- *Remedial Investigation/Feasibility Study at Eleven Sites, King Salmon Airport, King Salmon, Alaska* (SAIC, 1993b);
- *Remedial Investigation/Feasibility Study (RI/FS) at Twelve Sites, Stage 3, Part 1: Remedial Investigation, King Salmon Airport, King Salmon, Alaska* (EMCON, 1994a);
- *Remedial Investigation/Feasibility Study (RI/FS) at Twelve Sites, Stage 3, Part 2: Remedial Investigation, King Salmon Airport, King Salmon, Alaska* (EMCON, 1994b);
- Supplementary Well Construction Details and Groundwater Analytical Results for a Proposed French Drain at the former RAPCON/FT01 area (EMCON, 1994c);

- *Final Trip Report for Groundwater Monitoring Wells, King Salmon Alaska* (EMCON, 1995a);
- *Installation Restoration Program (IRP) Remedial Investigation Report at Twelve Sites* (EMCON, 1995b); and
- *Final Source Investigation and Removal Action Report for Fire Training Area 1* (EMCON, 1996).

The site-specific data presented in Sections 3, 4, and 5 are based on a review of these documents and on data collected by Parsons ES under this program.

SECTION 2

SITE CHARACTERIZATION ACTIVITIES

This section presents the methods used by Parsons ES personnel to collect site-specific data at Site FT01 and the RAPCON site, KSA, Alaska. To meet the requirements of the intrinsic remediation demonstration, additional data were collected during two site characterization events. The first characterization event was performed in September 1994, and consisted of monitoring well installation, soil and groundwater sampling, and aquifer testing to evaluate near-surface geology and geochemistry, aquifer properties, and the extent of soil and groundwater contamination for areas surrounding Site FT01. Well installation and soil sampling was accomplished during this investigation using HSA drilling in conjunction with continuous split-barrel sampling. Groundwater sampling was accomplished during this investigation using both newly installed monitoring wells and pre-existing monitoring wells. Aquifer slug tests were conducted at two newly installed wells. The second site characterization event was conducted in July 1995, and involved the manual installation of temporary monitoring points with Geoprobe® drive rods to delineate potential groundwater contamination at the RAPCON site and the potential for groundwater contamination from Site FT01 and/or the RAPCON site to migrate to Red Fox Creek. Groundwater samples were collected from monitoring wells and temporary monitoring points. Surface water and sediment samples also were collected along the segment of Red Fox Creek suspected of receiving groundwater discharge from Site FT01 and/or the RAPCON site.

The physical and chemical data listed below were collected during site characterization:

- Depth from measurement datum to the water table in monitoring wells (September 1994);
- Stratigraphy of subsurface media (September 1994);
- Hydraulic conductivity as determined from slug test data (September 1994);
- Groundwater geochemical data, including pH, temperature, electrical conductivity, total alkalinity, reduction/oxidation (redox), dissolved oxygen (DO), chloride, nitrate and nitrite nitrogen, ferrous iron, sulfate, manganese, carbon dioxide, total organic carbon (TOC), and methane (September 1994 and July 1995);
- Groundwater concentrations of aromatic volatile organic compounds (VOCs), chlorinated VOCs, and total fuel carbon (JP-4 range) (September 1994 and July 1995);

- Surface water and sediment concentrations of aromatic VOCs (July 1995); and
- Soil concentrations of aromatic VOCs, chlorinated VOCs, total fuel carbon, and TOC (September 1994).

In addition to the work conducted under this program, EMCON (1994a and 1994b) collected soil and groundwater data in October/November 1993 and September 1994 as part of RI/FS work for Site FT01. Data collected by EMCON were integrated with data collected under this program to develop the conceptual site model and to aid interpretation of the physical setting (Section 3) and contaminant distribution (Section 4).

The following sections describe the procedures that were followed when collecting site-specific data. The applied drilling, soil sampling, lithologic logging, and monitoring well installation and development procedures used in the September 1994 field characterization event are described in Section 2.1. The applied monitoring point installation and development procedures used in the July 1995 field characterization event are described in Section 2.2. Groundwater sampling procedures used for both site characterization events are described in Section 2.3. Surface water and sediment sampling procedures used in the July 1995 field sampling event are described in Sections 2.4 and 2.5, respectively. Procedures used for the testing of hydraulic conductivity in September 1994 are outlined in Section 2.6. General information on surveying performed at the study area are outlined in Section 2.7. Additional details regarding procedures used during investigative activities are presented in the draft TS work plan (ES, 1994).

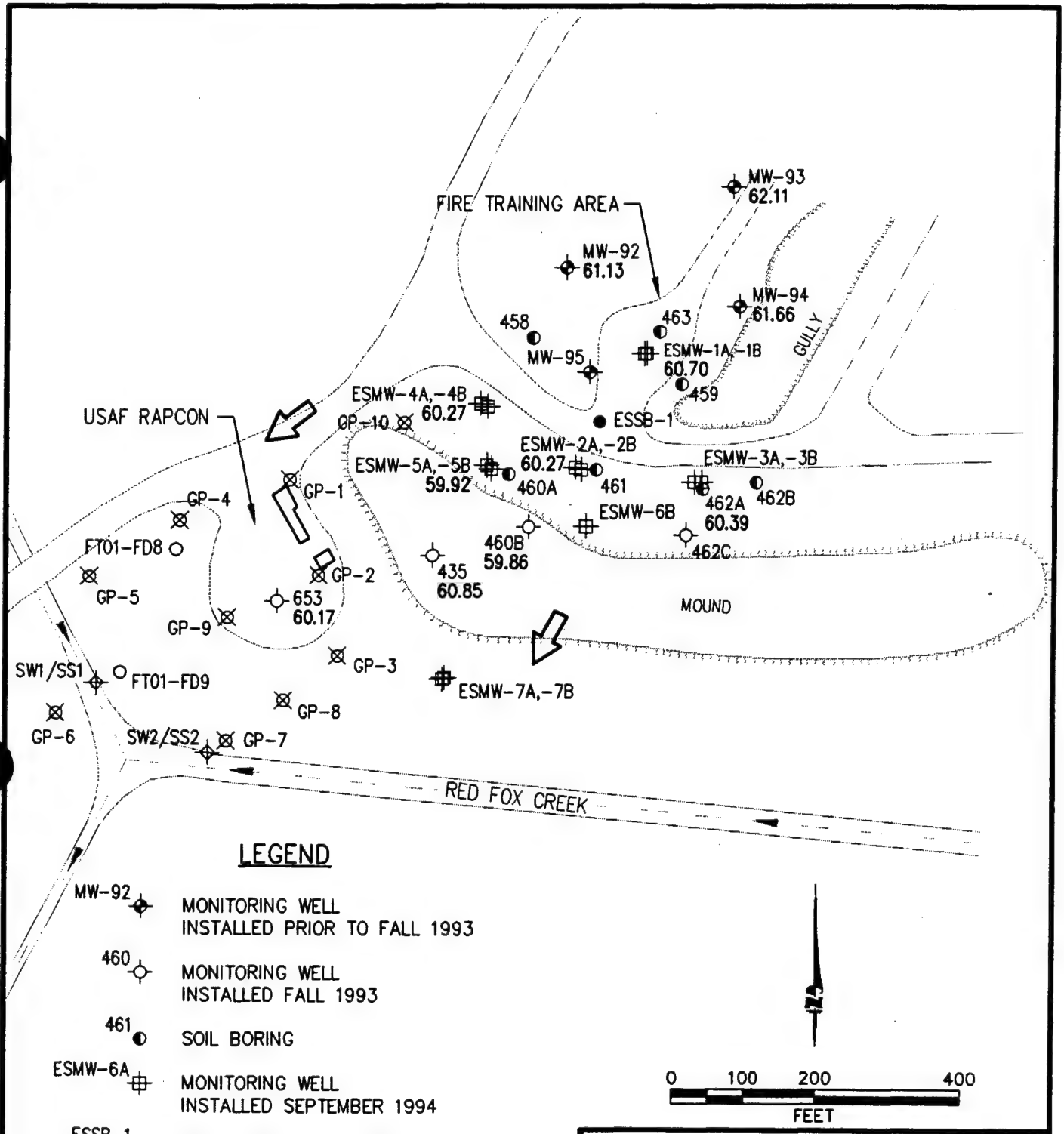
2.1 DRILLING, SOIL SAMPLING, AND MONITORING WELL INSTALLATION

2.1.1 Well Locations and Completion Intervals

Thirteen groundwater monitoring wells were installed at Site FT01 in September 1994 at seven locations to assist in the characterization of the shallow groundwater flow system at Site FT01. These wells were identified as ESMW-1A, ESMW-1B, ESMW-2A, ESMW-2B, ESMW-3A, ESMW-3B, ESMW-4A, ESMW-4B, ESMW-5A, ESMW-5B, ESMW-6B, ESMW-7A, and ESMW-7B. The new wells were installed in the locations shown on Figure 2.1. Table 2.1 presents well completion details. Nested well pairs were installed at six locations (ESMW-1 through ESMW-5, and ESMW-7) for vertical resolution of contaminants at the site. Nested wells were installed adjacent to each other, with one well (designated by the suffix "A") screened across the water table, and with the deeper well (designated by the suffix "B") screened approximately 13 to 19 feet below the bottom of the screen of the shallow well. The well locations were selected to provide the hydrogeologic data necessary for successful implementation of the Bioplume II model and to support intrinsic remediation.

2.1.2 Well Drilling and Soil Sampling Procedures

This section describes the procedures that were used for drilling and installation of the 13 monitoring wells. All monitoring wells were installed in accordance with general procedures outlined in Section 8.5 of *A Compendium of Superfund Field Methods* [US Environmental Protection Agency (USEPA), 1987].



LEGEND

- MW-92 — MONITORING WELL INSTALLED PRIOR TO FALL 1993
- 460 — MONITORING WELL INSTALLED FALL 1993
- 461 — SOIL BORING
- ESMW-6A — MONITORING WELL INSTALLED SEPTEMBER 1994
- ESSB-1 — SOIL BORING SEPTEMBER 1994
- SW1/SS1 — SURFACE WATER (SW) OR SURFACE SEDIMENT (SS) SAMPLING LOCATION
- FT01-FD8 — MONITORING WELL INSTALLED OCTOBER 1994
- GP-1 — TEMPORARY MONITORING POINT INSTALLED JULY 1995
- ESTIMATED GROUNDWATER FLOW DIRECTION

FIGURE 2.1

SAMPLING LOCATIONS

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

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Denver, Colorado

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TABLE 2.1
MONITORING WELL/POINT CONSTRUCTION DETAILS
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Well Designation	Installation Date	Northing	Easting	Well ID (inches)	Datum Elevation (ft mllw)[a/]	Ground Elevation (ft mllw)	Screen Interval Top (ft bgs)[b/]	Screen Interval Bottom (ft bgs)
MW-92	9/26/1992	1712583.48	759074.08	4	65.54	63.89	9.0	29.0
MW-93	9/26/1992	1712695.64	759302.66	4	61.46	59.49	5.0	25.0
MW-94	9/27/1992	1712530.15	759313.81	4	61.27	59.19	6.0	26.0
MW-95	9/28/1992	1712440.72	759106.08	4	61.16	59.19	7.5	27.5
435	10/19/1993	1712188.00	758891.84	2	66.84	64.49	15.0	25.0
460B	10/14/1993	1712227.06	759023.11	2	62.07	59.19	9.0	19.0
462C	10/14/1993	1712216.92	759240.51	2	53.56	52.09	4.0	14.0
653	5/8/1994	1712124.14	758675.30	2	60	57.19	9.5	19.5
ESMW-1A	9/13/1994	1712465.45	759184.27	2	62.89	60.49	13.0	18.0
ESMW-1B	9/14/1994	1712465.03	759181.18	2	62.98	60.49	31.1	36.1
ESMW-2A	9/13/1994	1712308.50	759087.81	2	63.8	61.09	13.0	18.0
ESMW-2B	9/15/1994	1712305.34	759095.54	2	63.77	61.09	35.0	40.0
ESMW-3A	9/13/1994	1712288.31	759251.29	2	62.85	60.49	12.0	17.0
ESMW-3B	9/15/1994	1712288.39	759261.32	2	63.41	60.49	33.2	38.2
ESMW-4A	9/12/1994	1712396.33	758956.47	2	63.71	60.99	13.0	18.0
ESMW-4B	9/15/1994	1712392.52	758966.38	2	63.64	60.99	32.0	37.0
ESMW-5A	9/12/1994	1712311.77	758965.66	2	54.57	51.89	4.0	9.0
ESMW-5B	9/19/1994	1712306.07	758971.82	2	55.02	51.89	22.1	27.1
ESMW-6B	9/17/1994	1712228.83	759102.06	2	55.7	52.99	23.0	28.0
ESMW-7A	9/11/1994	1712017.22	758908.72	2	60.15	57.09	8.0	13.0
ESMW-7B	9/12/1994	1712015.56	758905.10	2	59.69	56.89	25.5	30.5
FT01-FD8	10/17/1994	NA	NA	2	N/A	N/A	3.0	13.0
FT01-FD9	10/17/1994	NA	NA	2	N/A	N/A	3.0	13.0
GP-1	7/25/1995	NA[c/]	NA	0.25	N/A	N/A	17.4	18.0
GP-2	7/25/1995	NA	NA	0.25	N/A	N/A	15.3	15.8
GP-3	7/25/1995	NA	NA	0.25	N/A	N/A	14.0	14.5
GP-4	7/25/1995	NA	NA	0.25	N/A	N/A	13.0	13.5
GP-5	7/26/1996	NA	NA	0.25	N/A	N/A	10.0	10.5
GP-6	7/26/1996	NA	NA	0.25	N/A	N/A	7.5	8.0
GP-7	7/26/1996	NA	NA	0.25	N/A	N/A	7.5	8.0
GP-8	7/26/1996	NA	NA	0.25	N/A	N/A	10.5	11.0
GP-9	7/26/1996	NA	NA	0.25	N/A	N/A	10.5	11.0
GP-10	7/26/1996	NA	NA	0.25	N/A	N/A	10.5	11.0

[a/] ft mllw = Feet above mean lower low water level.

[b/] ft bgs = Feet below ground surface.

[c/] NA = Data not available.

2.1.2.1 Pre-Drilling Activities

All necessary digging, drilling, and groundwater monitoring well installation permits were obtained prior to mobilizing to the field. In addition, all utility lines were located, and proposed drilling locations were cleared prior to any drilling activities.

Water used in drilling, equipment cleaning, or grouting was obtained from an onsite potable water supply. Suitability of the water source was verified by contacting the appropriate facility personnel.

2.1.2.2 Equipment Decontamination Procedures

Prior to arriving at the site, and between each drilling location, the augers, drilling rods, bits, casing, samplers, tools, and other downhole equipment were decontaminated using a high-pressure, steam/hot water wash. Only potable water was used for decontamination.

During drilling operations, the drill rig, augers, and any downhole drilling equipment were decontaminated at a site decontamination pad. Water from the steam/hot water wash operation was allowed to collect in the decontamination pad and then treated by pumping through a granular activated carbon (GAC) unit. After treatment, water was stored in a 500 gallon holding tank. Water from the holding tank was eventually released into an on-site sanitary sewer. Precautions were taken to minimize any impact to the area surrounding the decontamination pad that might result from the decontamination operations.

Prior to use and between each sampling event, all sampling tools were cleaned onsite with a clean water/phosphate-free detergent mix, clean water rinse, and a methanol rinse. All decontamination activities were conducted in a manner so that the excess water was controlled and not allowed to flow into any open borehole.

Fuel, lubricants, and other similar substances were handled in a manner consistent with accepted safety procedures and standard operating practices. Well completion materials were not stored near or in areas that could be affected by these substances.

2.1.2.3 Drilling and Soil Sampling

Drilling was accomplished by using the HSA method. The borings were drilled and continuously sampled to the total depth of the borehole. Where two wells were installed adjacent to each other (i.e., nested), only the deeper well was logged and sampled. In many instances, sand heave below the water table prevented collection of continuous samples. A final borehole diameter of at least 8 inches was used for the installation of wells with a 2-inch inside-diameter (ID) casing.

Continuous soil samples were obtained using a 2.5-inch-ID split-barrel sampling device (i.e., a split spoon). Where possible, samples were collected continuously over the full depth of the soil borehole. Soil samples were removed from the split spoon as a composite of soil from 1-foot intervals and then placed in a clean glass jar for laboratory analysis. In addition, a portion of the soil sample was placed in an unused, sealable

plastic bag for photoionization detector (PID) headspace measurements for VOCs. Soil remaining in the spoon was used for lithologic and stratigraphic logging. Bags containing soil samples collected for the headspace procedure were quickly sealed and held for 15 minutes at an ambient temperature of 65 degrees Fahrenheit (°F) or greater. Semiquantitative measurements were made by puncturing the bag seal with the PID probe and reading the concentration of the headspace gases. The PID relates the concentration of total VOCs in the sample to an isobutylene calibration standard. The PID also was used to monitor the worker breathing zone.

The Parsons ES field hydrogeologist observed drilling and well installation activities and maintained a detailed descriptive log of subsurface materials recovered. Final geologic boring logs are presented in Appendix A. These logs contain:

- Sampled intervals (top and bottom depth);
- Presence or absence of contamination based on odor, staining, and/or PID readings;
- Soil description, including color, major textural constituents, minor constituents, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, and any other significant observations; and,
- Lithologic contacts, with the depth of lithologic contacts and/or significant textural changes recorded to the nearest 0.1 foot (1 inch).

At all borehole locations, one or two soil samples from the vicinity of the water table were selected for laboratory analysis. Where no elevated PID headspace readings were encountered, samples were collected from immediately above and/or immediately below the water table. Where PID readings were elevated, one of the samples submitted for laboratory analysis was from the interval giving the highest reading. Sample containers and appropriate container lids were provided by the USEPA mobile laboratory. Personnel from Parsons ES and the USEPA National Risk Management Research Laboratories (NRMRL) [formerly the Robert S. Kerr Environmental Research Laboratory (RSKERL)] participated in soil sampling. USEPA NRMRL was responsible for sample analysis.

The sample containers were filled as full as possible to minimize headspace in the jars, and the container lids were tightly closed. A sample label was firmly attached to the container side, and the following information was legibly and indelibly written on the label:

- Sample identification;
- Sample depth;
- Sampling date; and,
- Sample collector's initials.

After the samples were sealed and labeled, they were placed in a cooler with ice and held for transport to the onsite USEPA mobile laboratory. The VOC analysis for soil samples included benzene, toluene, ethylbenzene, and xylenes (BTEX), total fuel carbon, tetrachloroethene (PCE), and trichloroethene (TCE).

All soils were initially drummed and stored near the monitoring wells during the drilling operations (ES, 1994). Soils at the site were eventually transferred to a soil farm specifically designed for the bioventing of petroleum-hydrocarbon-contaminated soils and maintained by the 11th Civil Engineering Operations Squadron (CEOS).

2.1.3 Monitoring Well Installation

Groundwater monitoring wells were installed in 13 borings at 7 locations under this program. Detailed well installation procedures are described in the following paragraphs. Well completion diagrams are included in Appendix A.

2.1.3.1 Well Materials Decontamination

All well completion materials were factory sealed and were inspected by the field hydrogeologist and determined to be clean and acceptable prior to use. Pre-packaged sand, bentonite, and concrete mix were used in well construction, and the bags were inspected for possible external contamination before use. Materials that could not be cleaned to the satisfaction of the field hydrogeologist were not used.

2.1.3.2 Well Casing

Upon completion of drilling to the proper borehole termination depth, a monitoring well casing was installed. Well construction details were noted on a Monitoring Well Installation Record form. This information became part of the permanent field record for the site. Monitoring well installation forms for Site FT01 are presented in Appendix A.

Blank well casing consisted of Schedule 40 polyvinyl chloride (PVC) with an ID of 2 inches. All well casing sections were flush threaded, and glued joints were not used. The casing at each well was fitted with a vented top cap constructed of the same type of material as the well casing.

The field hydrogeologist verified and recorded the boring depth, the lengths of all casing sections, and the depth to the top of all well completion materials placed in the annulus between the casing and borehole wall. All lengths and depths were measured to the nearest 0.1 foot.

2.1.3.3 Well Screen

Well screens consisted of flush-threaded, Schedule 40 PVC with an ID of 2 inches. The screens were 5 feet in length and factory slotted with 0.010-inch openings. Each shallow well was screened so that seasonal fluctuations of the water table can be measured and so that mobile LNAPL (if present) can be detected. For nested wells, the deep wells were screened at depths ranging from 13 to 19 feet below the bottom of the shallow screen. Well screen positions were selected by the field hydrogeologist after

consideration was given to the geology and hydraulic characteristics of the stratum in which the wells were screened.

2.1.3.4 Sand Filter Pack

A graded sand filter was placed around the screened interval from the bottom of the casing to approximately 2 feet above the top of the screen. Number 10-20 Colorado silica sand was used for the sand filter pack. Placement of a sand filter pack around the deep monitoring well screens was occasionally compromised from heaving formation sands being forced into the HSA by hydrostatic pressures. Large quantities of potable water (up to 50 gallons) were used to install the sand filter packs in the deep wells. The addition of water into the well bore during well installation increases the downward pressure head within the bore, helping to offset the hydraulic pressure created by the formation at depth, and reducing the heave of formation sands within the well bore. Formation soil was a coarse sand that prohibited the breaching or clogging of well screens, and well development (described in Section 2.1.4) proceeded without incident.

2.1.3.5 Annular Sealant

A seal of sodium bentonite chips was placed above the sand filter pack in all wells. The filter pack seal was a minimum of 2 feet thick and, where placed above the water table, was hydrated in place with potable water. In all wells at Site FT01, the remainder of the annular seal up to the surface also consisted of hydrated bentonite chips. This seal was selected because the water table was shallow enough to omit the use of bentonite grout.

For both shallow and deep wells, the protective casings were set into the upper 2 to 2.5 feet of the annular seal. The casings were not cemented in place in order to reduce the potential of frost heave damage. Bentonite remains plastic at low temperatures, thereby minimizing shear between the annular seal, the surrounding earth, and the protector pipe. Pure sodium bentonite has a permeability low enough to provide a sufficient borehole seal. To minimize dehydration and protect the bentonite, a 6-inch thick gravel pad was placed on top of the seal surrounding the protector casing.

2.1.3.6 Protective Cover

Each monitoring well was completed with a 6-inch by 6-inch aboveground protective cover with a locking cap. The tops of the covers were placed approximately 3 feet above grade, with a gravel pad surrounding the base of the cover. Well identifications were permanently affixed to the wells by stamping the well identification onto the protective cover.

2.1.4 Well Development

Prior to sampling, newly installed monitoring wells were developed. Well development removes sediment from inside the well casing and flushes fines, cuttings, and drilling fluids from the sand pack and the portion of the formation adjacent to the well screen.

A minimum of 10 well volumes was purged from each monitoring well. Well volume was estimated from water levels and well depths measured with an electronic water level probe. Water characteristics such as appearance and odor were recorded by the Parsons ES field both prior to development and after development. The beginning and ending time of the development process also were recorded in the well development record for each well.

Well development was accomplished using an inertial pump. The upward inertial flow of water was created by a rapid upward/downward movement of high-density polyethylene tubing (HDPE) that was connected to the crankshaft of a small, 3-horsepower engine. Water was prevented from leaving the downhole end of the tube by a Waterra® stainless steel footvalve fitted to the end of the tubing. The movement of the tubing and footvalve in the well created agitation in the casing that helped remove fine-grained materials from the monitoring well. All well development waters were collected in 55-gallon steel drums and transported to the decontamination pad for treatment with GAC, and then disposed of in the sanitary sewer (see Section 2.1.2.2). All footvalves and tubing were decontaminated by steam-cleaning between wells.

2.2 MONITORING POINT INSTALLATION AND DEVELOPMENT

Ten temporary monitoring points were installed in July 1995 to assist in the characterization of the shallow groundwater flow system downgradient (southwest) of Site FT01 and to assess potential groundwater contaminant discharge to Red Fox Creek. These temporary monitoring points were identified as GP-1 through GP-10. The new monitoring points were manually installed in the locations shown on Figure 2.1. Table 2.1 presents monitoring point completion details. All temporary monitoring points were screened over an interval of 0.5 feet, approximately 1 to 2 feet below the water table. The monitoring point locations were selected to provide the hydrogeologic data necessary for successful implementation of the Bioplume II model and to support intrinsic remediation.

2.2.1 Pre-Placement Activities

All necessary digging and groundwater monitoring point installation permits were obtained prior to mobilizing to the field. In addition, all utility lines were located, and proposed point locations were cleared prior to any placement activities.

Water used in monitoring point placement or equipment cleaning was obtained from an onsite potable water supply. Suitability of the water source was verified by contacting the appropriate facility personnel.

2.2.2 Equipment Decontamination Procedures

Prior to arriving at the site, and between each monitoring point location, the Geoprobe® drive rods, tips, sleeves, tools and other downhole equipment were decontaminated using an Alconox® detergent and potable water solution followed by a potable water wash. All equipment also underwent a rinse with isopropyl alcohol, followed by a final rinse with deionized water.

Fuel, lubricants, and other similar substances were handled in a manner consistent with accepted safety procedures and standard operating practices. Well completion materials were not stored near or in areas that could be affected by these substances.

2.2.3 Monitoring Point Installation

Temporary monitoring points consisted of a 1.3-inch OD aluminum drive point, a 0.25-inch ID by 6-inch long stainless steel mesh implant (acting as a screen), and 0.25-inch ID HDPE tubing. Monitoring point completion materials were inspected by the field hydrogeologist and determined to be clean and acceptable prior to use. All monitoring point completion materials were factory sealed. Pre-packaged tubing and stainless steel implants were used in well construction. Materials that could not be cleaned to the satisfaction of the field hydrogeologist were not used.

Monitoring points were placed by driving lengths of 1.0-inch-OD probe rod to the desired depth with a 30-pound manual probe rod driver. The downhole end of the drive rod was prefitted with a sacrificial aluminum drive point to decrease soil resistance and to prevent soils from entering the drive rod. After reaching the desired depth, a stainless steel mesh implant was connected to HDPE tubing and threaded through the center of the Geoprobe® drive rod. The drive rods were then removed with a probe rod jack, leaving the sacrificial tip, screen, and riser tubing in the formation at the desired depth. Formation soils quickly collapsed into the borehole after the removal of the drive rod to create a natural sand pack. As a result of soils quickly collapsing to the ground surface, no annular sealants (e.g., bentonite) could be placed as a seal around the tubing.

The field hydrogeologist verified and recorded the drive depth and the lengths of all riser tubing used. All lengths and depths were measured to the nearest 0.1 foot.

2.2.4 Monitoring Point Development

Prior to sampling, newly installed monitoring points were developed. Development removes fine sediment from inside the stainless steel mesh implant and flushes fines from the natural sand pack adjacent to the mesh implant. Water characteristics such as appearance and odor were recorded by the Parsons ES field both prior to development and after development. The beginning and ending times of the development process were also recorded in the development record for each point.

Monitoring point development was accomplished using a peristaltic pump with dedicated silicon and HDPE tubing. Development was continued until 10 tubing volumes of water were removed, and pH, temperature, and conductivity of the groundwater had stabilized. Small volumes of development waters were produced (i.e., several liters per location) and were redistributed on the ground surface near the monitoring point being developed.

2.3 GROUNDWATER SAMPLING

Personnel from Parsons ES and the USEPA NRMRL participated in groundwater sampling. USEPA NRMRL was responsible for sample analysis. In September 1994, groundwater samples were collected from 7 existing and the 13 newly installed

monitoring wells (Figure 2.1). Existing wells that were sampled included MW-92, MW-93, MW-94, MW-95, 460B, 462C, and 435.

In July 1995, groundwater samples were collected from 16 of the 20 wells sampled in September 1994, and the 10 newly installed monitoring points. The monitoring points were installed at the locations shown on Figure 2.1. Existing wells that were sampled included ESMW-1A, ESMW-1B, ESMW-2A, ESMW-2B, ESMW-3A, ESMW-4A, ESMW-5A, ESMW-5B, ESMW-6B, MW-92, MW-93, MW-94, MW-95, 460B, 462C, and 435.

Groundwater samples were analyzed by USEPA NRMRL personnel in the field in September 1994 and July 1995 for alkalinity, DO, ferrous iron, free carbon dioxide, pH, phenols, redox potential, soluble manganese (September 1994), sulfides, and temperature. Analyses for ammonia, chloride, conductivity, methane, metals (September 1994 only), nitrate and nitrite, sulfate, purgeable aromatic hydrocarbons, total fuel hydrocarbon, and chlorinated aliphatic hydrocarbons were performed at the NRMRL in Ada, Oklahoma.

This section describes the procedures used for collecting groundwater quality samples. In order to maintain a high degree of quality control (QC) during this sampling event, the procedures described in the site work plan (ES, 1994) and summarized in the following sections were followed.

2.3.1 Preparation for Sampling

All equipment used for sampling was assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials were gathered prior to leaving the office.

All portions of sampling and test equipment that contacted the sample were thoroughly cleaned before use. This equipment included the water level probe and cable, peristaltic pump tubing, equipment for measuring onsite groundwater chemical parameters, and other equipment that contacted the samples. The following cleaning protocol was used:

- Cleaned with potable water and phosphate-free laboratory detergent;
- Rinsed with potable water;
- Rinsed with distilled or deionized water;
- Rinsed with reagent-grade acetone; and
- Air dried prior to use.

Any deviations from these procedures were documented in the field scientist's field notebook and on the groundwater sampling form.

As required, field analytical equipment was calibrated according to the manufacturers' specifications prior to field use. This requirement applied to equipment used for onsite

chemical measurements of DO and temperature. USEPA NRMRL personnel were responsible for calibrating equipment utilized in the USEPA mobile laboratory.

2.3.2 Groundwater Sampling Procedures

Special care was taken to prevent contamination of the groundwater and extracted samples through cross contamination from improperly cleaned equipment. Water level probes and cable used to determine static water levels and well total depths were thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 2.2.1. In addition, a new pair of disposable latex gloves was worn each time a different well was sampled.

2.3.2.1 Preparation of Location

Prior to starting the sampling procedure, the area around the well/point was cleared of foreign materials, such as brush, rocks, and debris. These procedures prevented sampling equipment from inadvertently contacting debris around the monitoring well/point.

2.3.2.2 Water Level and Total Depth Measurements

The static water level was measured prior to removing any water from monitoring wells. Static water levels were not measured in monitoring points with 0.25-inch-ID HDPE riser tubing. An electrical water level probe was used to measure the depth to groundwater below the well datum to the nearest 0.01 foot. After measurement of the static water level, the water level probe was lowered to the bottom of the well for measurement of total well depth (recorded to the nearest 0.01 foot). Based on these measurements, the volume of water to be purged from the wells was calculated.

2.3.2.3 Well/Point Purging

A peristaltic pump with dedicated polyethylene tubing was used for well evacuation. Groundwater was removed from each monitoring well prior to sampling and until DO, pH, redox, and conductivity readings had stabilized. Purge waters generated during the September 1994 site characterization event were placed in 55-gallon steel drums and transported to the temporary decontamination pad used for steam-cleaning of augers. Purge water was treated with GAC and disposed of in an on-Base sanitary sewer. Low volumes of purge water were generated from monitoring points and monitoring wells in the July 1995 site characterization event, and water was redistributed to the ground surface near the monitoring well/point.

2.3.2.4 Sample Extraction

A peristaltic pump with dedicated polyethylene tubing was used to extract groundwater samples from the well/point. The sample was transferred directly into the appropriate sample container. The water was carefully poured down the inner walls of the sample bottle to minimize aeration of the sample. Sample bottles for VOCs and total fuel carbon analysis were filled so that there was no headspace or air bubbles within the container. VOCs analyzed in water samples were BTEX, trimethylbenzene compounds,

chlorinated compounds [including PCE, TCE, cis- and trans-dichloroethene (DCE), and vinyl chloride].

2.3.3 Onsite Chemical Parameter Measurement

2.3.3.1 Dissolved Oxygen Measurements

DO measurements were taken using an Orion® model 840 or YSI-55 DO meter in a flow-through cell at the outlet of the peristaltic pump. DO concentrations were recorded after the readings stabilized, and in all cases represent the lowest DO concentration observed.

2.3.3.2 Electrical Conductivity, pH, Redox Potential, and Temperature Measurements

Because the electrical conductivity, pH, redox potential, and temperature of groundwater can change significantly within a short time following sample acquisition, these parameters were measured in the field using Orion 290 and 250 meters, in the same flow-through cell used for DO measurements. The measured values were recorded on the groundwater sampling record (Appendix C).

2.3.4 Sample Handling

2.3.4.1 Sample Containers, Preservation, and Labels

The USEPA provided appropriate pre-preserved sample containers. The sample containers were filled as described in Sections 2.3.3.4, and the container lids were tightly closed. The sample label was firmly attached to the container side, and the following information was legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (groundwater);
- Sampling date;
- Sampling time;
- Preservatives added; and
- Sample collector's initials.

2.3.4.2 Sample Shipment

After the samples were sealed and labeled, they were transported to the on-site USEPA laboratory for packing and shipment. The following packaging and labeling procedures were followed:

- Samples were packaged to prevent leakage or vaporization from the containers;
- Samples were cushioned to avoid breakage; and
- Ice was added to the cooler to keep the samples cool.

The packaged samples for fixed-base laboratory analysis were delivered by overnight courier (Federal Express®) to the USEPA NRMRL in Ada, Oklahoma. Hach® and CHEMetric® laboratory samples were hand delivered to the on-Base NRMRL laboratory.

2.4 SURFACE WATER SAMPLING

Two surface water samples (SW1 and SW2) were collected in July 1995 from Red Fox Creek, southwest of Site FT01 (Figure 2.1). The samples were collected near FT01-FD9 and monitoring point GP-7 to assess the impact of groundwater seeps along the bank on surface water quality.

Surface water samples were collected directly into the sample bottle by placing the sample bottle in the creek with the opening facing up and allowing the water to slowly fill the bottle. Sample handling proceeded as described for groundwater samples in Section 2.3.5. The samples were analyzed for aromatic VOCs.

2.5 SEDIMENT SAMPLING

Two sediment samples (SS1 and SS2) were collected in July 1995 from the bottom of Red Fox Creek at the same locations that surface water samples were collected (Figure 2.2). The samples were collected in order to assess the potential accumulation in creek sediments of fuel contaminants that have migrated from the study area. Sediment samples were analyzed for aromatic VOCs.

Sediment samples were collected with a steel shovel. All sediment samples were collected from the uppermost 4 inches of the sediment column. Sediment samples were not composited. The saturated sediments were immediately placed in analyte appropriate containers, as described in Section 2.1.2.3.

2.6 AQUIFER TESTING

Slug tests were performed in September 1994 in wells ESMW-1A and ESMW-2A (Figure 2.1) to provide estimates for the hydraulic conductivity of the shallow saturated zone in the vicinity of Site FT01. Slug tests are single-well hydraulic tests used to estimate the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug testing can be performed using either a rising head or a falling head test. Both rising head and falling head tests were used at this site. Detailed slug testing procedures are presented in the *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater* (Wiedemeier *et al.*, 1995), hereafter referred to as the Technical Protocol document.

Data obtained during slug testing were analyzed using the computer program AQTESOLV® (Geraghty & Miller, Inc., 1994) and the methods of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. The results of slug testing are presented in Section 3.3 and Appendix A.

2.7 SURVEYING

After completion of field work in September 1994, the locations and elevations of all new monitoring wells were surveyed by Coastal Surveyors, a licensed land surveying company from Naknek, Alaska. The horizontal locations and elevations of the measurement datum (top of PVC well casing) and the ground surface adjacent to the well casing were measured relative to existing control points referenced to the Alaska State plane coordinate system. Horizontal locations were surveyed to the nearest 0.1 foot. Measurement datum and ground surface elevations were surveyed to the nearest 0.01 foot and referenced to mean lower low water (mllw) elevation. The mllw elevation is the average height of the lower-low water at a specific location over a 19-year period. An approximation of this level, called lower-low water datum, was used as the tidal datum for study area survey and is commonly used as a tidal datum along the pacific coast of the United States. Survey data are presented in Table 2.1 and Appendix A. The locations of temporary monitoring points placed in July 1995 were estimated by measuring the distance between the monitoring points and adjacent monitoring wells and/or surface buildings.

SECTION 3

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section incorporates data presented by SAIC (1993b) and EMCON (1994a and 1994b) with data collected by Parsons ES in conjunction with researchers from the USEPA NRMRL in September 1994. Investigative techniques used by Parsons ES and NRMRL personnel to determine the physical characteristics of Fire Training Area 1 and the RAPCON site are discussed in Section 2.

3.1 SURFACE FEATURES

3.1.1 Topography and Surface Water Hydrology

Site FT01 is located in a largely undeveloped, wooded section of KSA with minor vertical relief. Major land features include a 10-foot-deep gully to the east of the site, a gully to the south of the fire training pit, and a small wooded mound running east/west that separates the fire training pit from Red Fox Creek. The closest segment of Red Fox Creek lies approximately 600 feet south of the fire training pit, and is the surface water body closest to the fire training area. Red Fox Creek discharges to the Naknek River, the closest segment of which is located approximately 4,000 feet southwest of the fire training area (Figure 1.3).

Small topographic gradients along Red Fox Creek cause wetland conditions during periods of high precipitation. Vegetation along Red Fox Creek is characterized by long-leaf grasses and mounds of deep-rooted foliage. Water flow within the wetlands is relatively slow, and water in Red Fox Creek can vary in depth, specifically in the northwest/southeast branch of the creek (Figure 1.4), from dry to several feet deep, depending on seasonal and climatological conditions.

3.1.2 Manmade Features

No manmade structures exist in or adjacent to the fire-training pit. A mock aircraft that formerly existed in the fire training pit was used in fire-training operations. However, the mock plane was removed when the fire training pit soils were excavated in July 1995 (EMCON, 1996a). An unpaved access road south of the pit connects the site to the rest of the Base (Figure 1.3). Some partially exposed piping extends from the fire training pit to an area 180 feet northwest, near MW-92, and is believed to have been used to transfer fuels to the fire training pit. Approximately 700 feet southwest of the site is the former RAPCON site and two equipment buildings (Figure 1.4). Nearly 250 feet east of the radar structure and 200 feet west of monitoring well 435, is a high-voltage transfer

box supplying power to the radar structure. The radar structure was disassembled in September 1994 during the site characterization event performed by Parsons ES.

3.2 CLIMATE

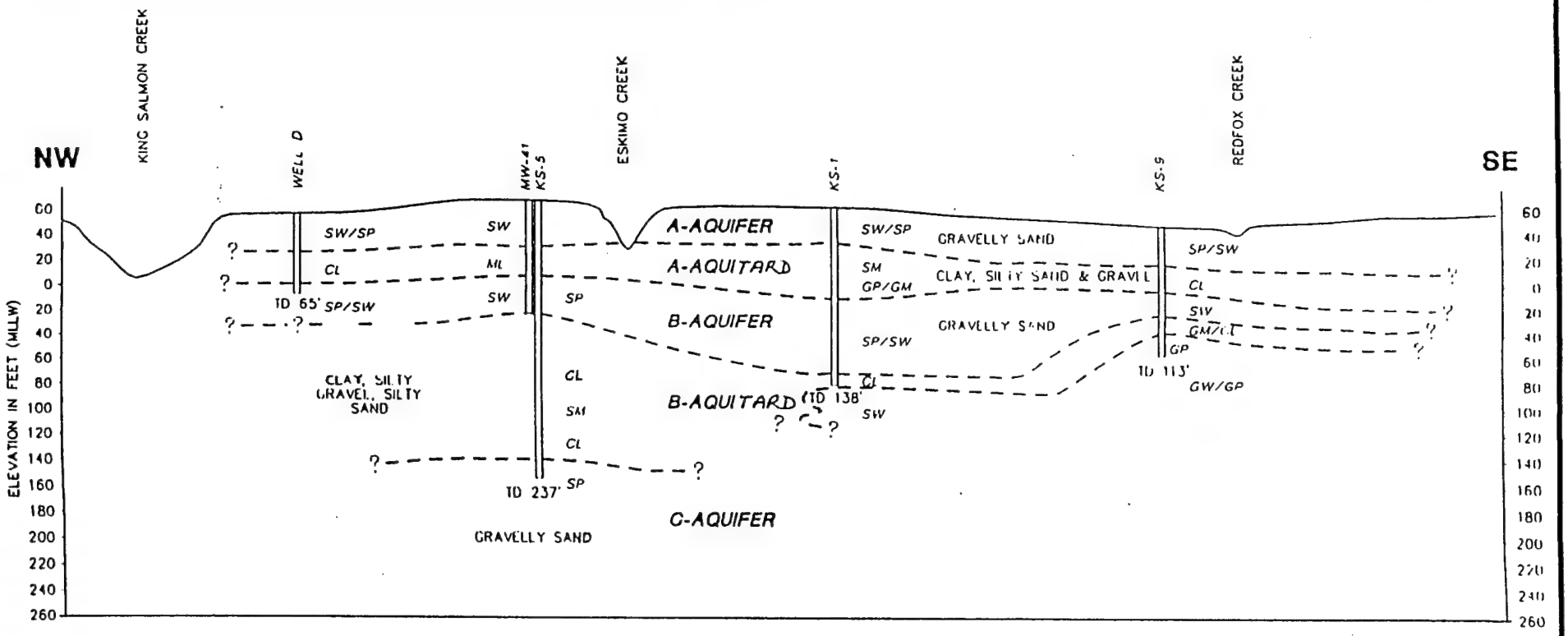
The King Salmon area experiences a transitional climate between the continental temperature extremes encountered in interior Alaska, and the milder coastal maritime climate. Mean annual temperature is 33 °F, with a recorded range of -46°F in January to 88°F in June. Mean annual precipitation is approximately 20 inches. The majority of rainfall occurs in late summer and fall. Snowfall averages 46 inches per year, with a monthly recorded maximum of 20 inches in March. Discontinuous permafrost is encountered in the KSA area, with known occurrences east of the Upper Naknek area at Eskimo Creek and in the wetlands west of the Eskimo Creek/Naknek River confluence (Figure 1.3).

3.3 REGIONAL GEOLOGY AND HYDROGEOLOGY

KSA is situated on a segmented volcanic arc of the Aleutian arc-trench system. This arc-trench system continues to form along the collision boundary between the northward-moving Pacific tectonic plate as it is subducted beneath the west/southwest-moving North American tectonic plate. Hence, the entire Alaska-Aleutian peninsula is an intensively active seismic zone. Within the eastern Aleutian arc, 10 of 22 volcanoes spanning the 336-mile-long volcanic front have erupted in recorded history, and another 6 exhibit signs of hydrothermal activity. The rugged mountain peaks along the southeastern coast of the Alaskan Peninsula are the surface manifestation of volcanic intrusions and distributed sediments from earlier, arc-related volcanoes. The lowland areas of the Alaskan Peninsula are generally mantled by highly eroded Tertiary volcanic rock, which contributes to the subdued topographic expression of the Nushagak-Bristol Bay Lowland.

The upper few hundred feet of unconsolidated soils in the KSA area consist of glacial sediments deposited during the three distinct Pleistocene glacial events. These deposits have been reworked by marine tidal, braided stream, glacio-fluvial, and glacio-lacustrine processes, and consist of unconsolidated, poorly to moderately well-sorted gravels, sands, silts, and clays. A generalized regional cross-section of the area is shown in Figure 3.1.

Three aquifers are present in the vicinity of KSA. The aquifers consist of unconsolidated well to poorly sorted, silty and gravelly sands separated by aquitards (confining layers) consisting of silty and clayey gravels, silts, and clays. The shallowest aquifer, the "A-Aquifer", is unconfined in nearly all locations at KSA. This aquifer consists of moderately well-sorted sands and silty sands with discontinuous lenses of medium- to coarse-grained gravel at its base. Static water levels vary from the surface in creeks and wetlands to as much as 30 feet below ground surface (bgs) on the northern side of KSA. Discontinuous permafrost may act locally as an impermeable barrier to the flow of groundwater. The A-aquifer is likely recharged by precipitation and influent stream flow. The general flow pattern of groundwater is toward topographically lower local areas, streams, and wetlands.



EXPLANATION

KS	KING SALMON AIRPORT BASE PRODUCTION WELL
MW	MONITORING WELL
TD	TOTAL DEPTH
CL	UNIFIED SOIL CLASSIFICATION SYMBOL

Source: EMCON, 1994a.

FIGURE 3.1

GENERALIZED HYDROGEOLOGIC CROSS-SECTIO FOR KING SALMON AIRPORT

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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Underlying the A-Aquifer is a zone of lower hydraulic conductivity consisting of gravelly, clayey silt, silty clay, and sandy silt. This unit is called the "A-Aquitard." The aquitard varies from 7 to 22 feet thick, and was previously reported to locally disrupt and modify the regional unconfined groundwater flow pattern for the A-Aquifer, especially in areas where the aquitard is thickest (SAIC, 1993b).

Below the A-Aquitard is the "B-Aquifer." The top of the B-Aquifer is encountered between 50 and 80 feet bgs at KSA. The B-Aquifer is suspected to be a semiconfined aquifer and is comprised of interbedded sequences of silty sands, sandy gravels, and silty to sandy gravels. The potentiometric surface of the B-Aquifer in some wells is close to the A-Aquifer water table elevation in neighboring wells. Groundwater movement in the B-Aquifer is generally to the south.

Underlying the B-Aquifer is a second aquitard called the "B-Aquitard." The thickness of this second aquitard is estimated to be between 10 and 120 feet. This unit is predominantly sandy clay.

Limited data are available concerning the third water-bearing unit at KSA, the "C-Aquifer". The C-Aquifer underlies the B-Aquitard at approximately 200 feet bgs. This aquifer is suspected to be confined. KSA water supply wells are completed in the C-Aquifer. The thickness of this aquifer is unknown, but may be up to 20 feet based on data from water supply well KS-5 at KSA (Figure 3.1). No data are available concerning the direction of groundwater flow in the C-Aquifer.

3.4 SITE GEOLOGY AND HYDROGEOLOGY

3.4.1 Lithology and Stratigraphic Relationships

In order to illustrate stratigraphic relationships at Site FT01, hydrogeologic cross-sections have been developed from subsurface data derived from borehole logs for monitoring wells ESMW-1A through ESMW-5B, 653, and FT01-FD9, and soil borehole ESSB-1. Figure 3.2 shows the locations of the borings (most of which were completed as monitoring wells) and hydrogeologic sections A-A' and B-B'. Figures 3.3 and 3.4 present hydrogeologic sections A-A' and B-B', respectively, and show the relationship between the groundwater surface and the stratigraphy at the site. The saturated thickness of the aquifer at Site FT01 appears to be between 30 and 35 feet. The underlying A-Aquitard, which confines the bottom of the surface aquifer at depth, consists of gray, clayey silt to silty clay. Red Fox Creek intersects the shallow aquifer, and may act as either a recharge or a discharge point, depending on seasonal precipitation and local drainage. No permafrost was encountered in soil borings drilled as part of this TS.

The glacially deposited sediments dominating the surficial deposits at Fire Training Area 1 consist of very homogeneous fine- to medium-grained sands. The few observed variations in soil type consisted of isolated layers of pebbles or silty clay that were several inches thick (ESMW-5B). On the basis of available soil borehole logs for monitoring wells 653 and FT01-FD9, the surficial soils in the vicinity of the RAPCON site are similar. The A-aquitard separating the A-aquifer from the B-aquifer at the site was not identified at the Fire Training Area; however, the top of the confining layer may

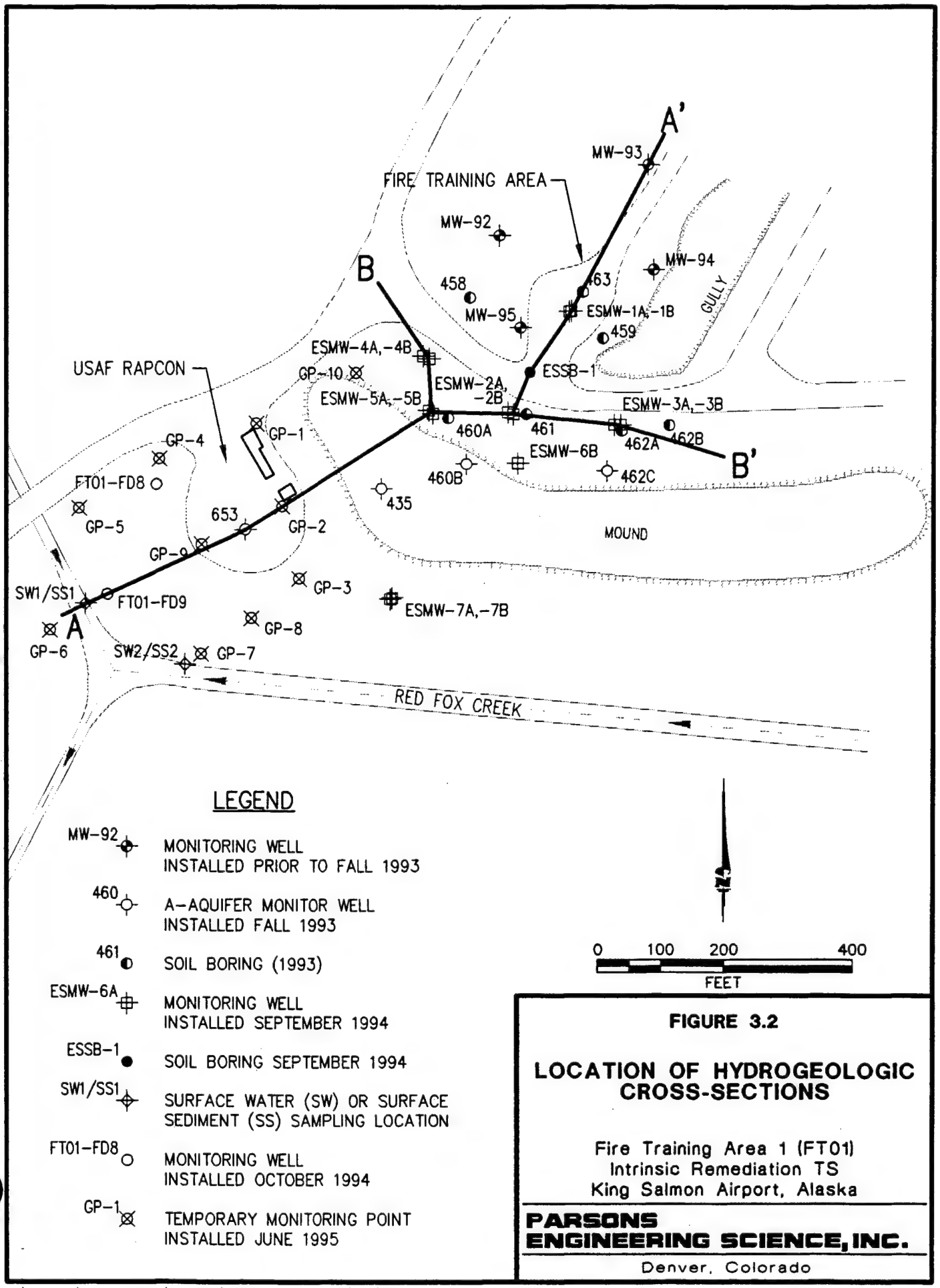

FIGURE 3.2

LOCATION OF HYDROGEOLOGIC CROSS-SECTIONS

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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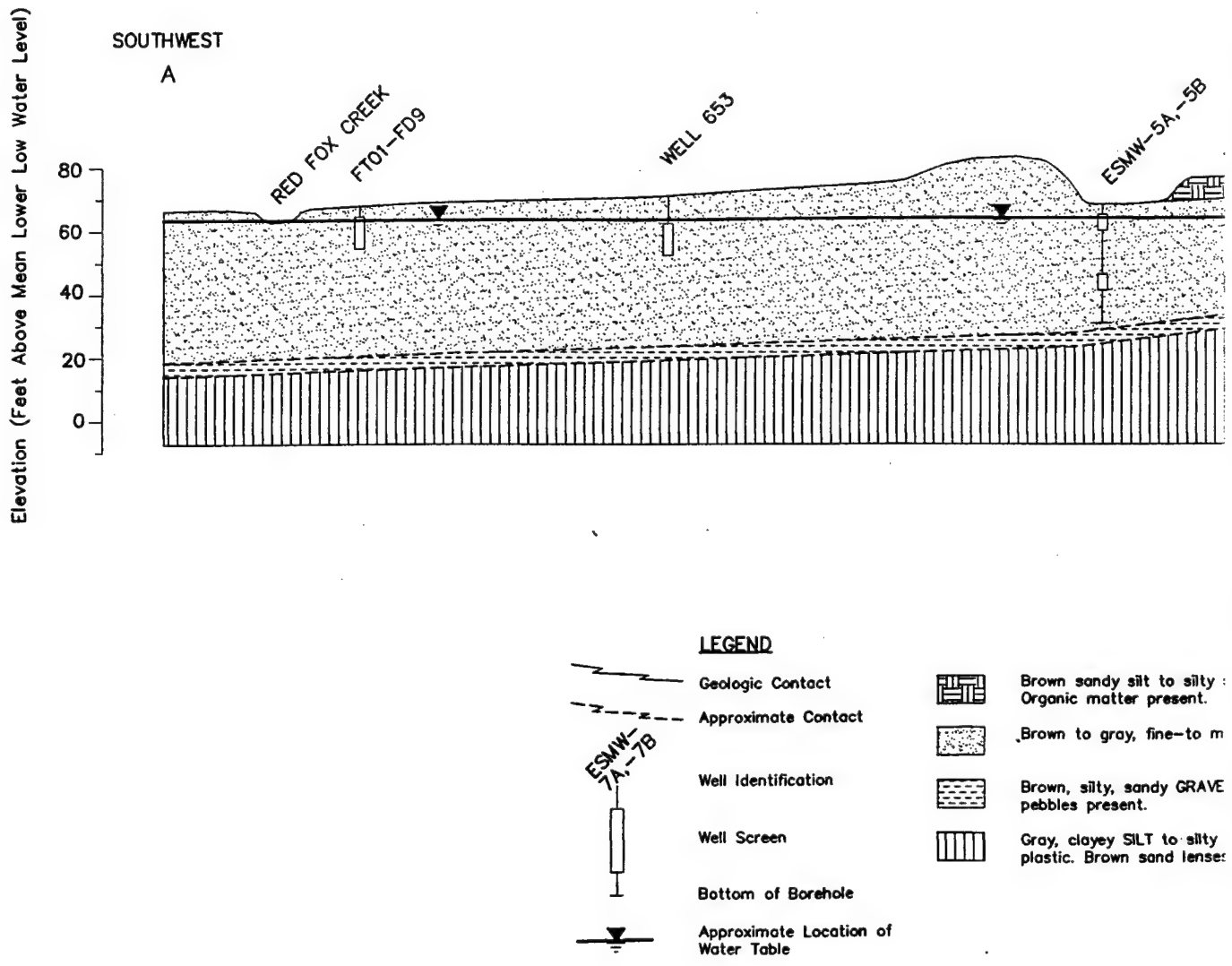

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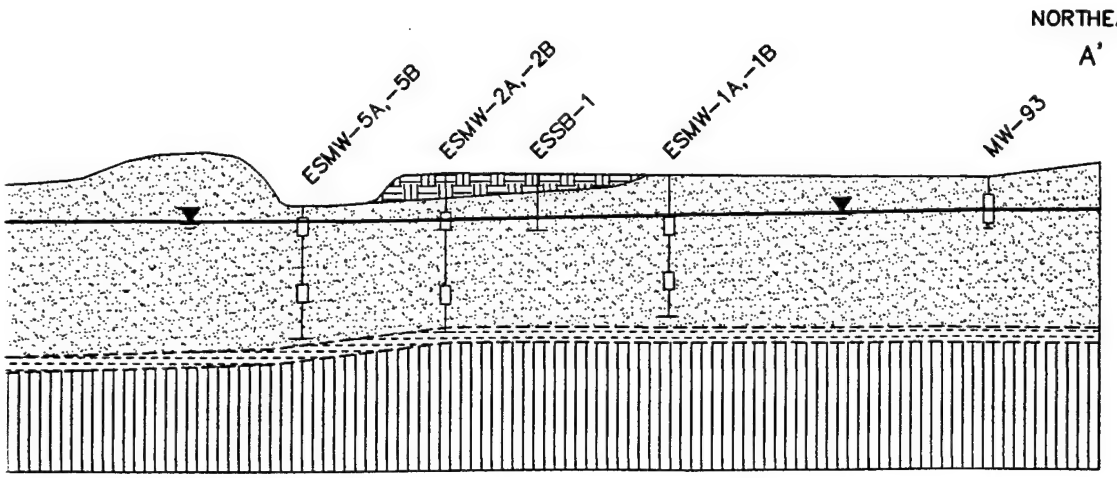


Brown sandy silt to silty sand FILL. Organic matter present.

Brown to gray, fine-to medium-grained SAND.

Brown, silty, sandy GRAVEL. Some subrounded pebbles present.

Gray, clayey SILT to silty CLAY. Dense and highly plastic. Brown sand lenses present.

VERTICAL EXAGGERATION 2.5x

0 100 200

FEET

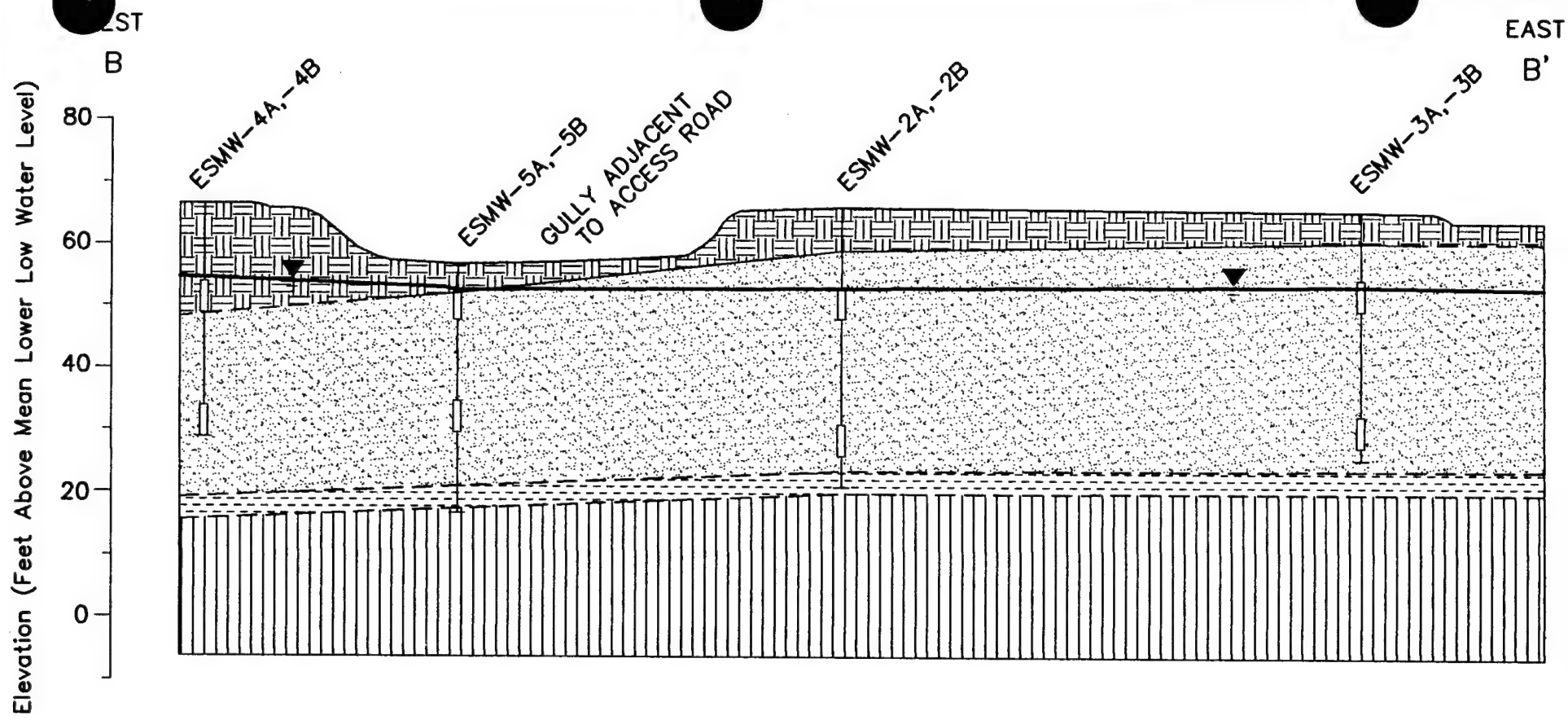
FIGURE 3.3

HYDROGEOLOGIC CROSS-SECTION A-A'

Fire Training Area 1 (FT-01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado



VERTICAL EXAGGERATION 2x

0 25 50 100

FEET

LEGEND

- Geologic Contact
- Approximate Contact
- ES-MW-4A,-4B — Well Identification
- Well Screen
- Bottom of Borehole
- Approximate Location of Water Table
- Brown sandy silt to silty sand FILL. Organic matter present.
- Brown to gray, fine-to-medium grained SAND.
- Brown, silty, sandy GRAVEL. Some subrounded pebbles present.
- Gray, clayey SILT to silty CLAY. Dense and highly plastic. Brown sand lenses present.

FIGURE 3.4

HYDROGEOLOGIC CROSS-SECTION B-B'

Fire Training Area 1 (FT-01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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have been encountered at soil borehole ESMW-2B. Drillers experienced with the stratigraphy in KSA area report that the A-Aquitard is typically overlain by zones of pebbles and gravel above the less permeable layers of clays and silts. Silty sand with gravel was encountered at 43 feet bgs in the borehole for well ESMW-2B.

3.4.2 Groundwater Hydraulics

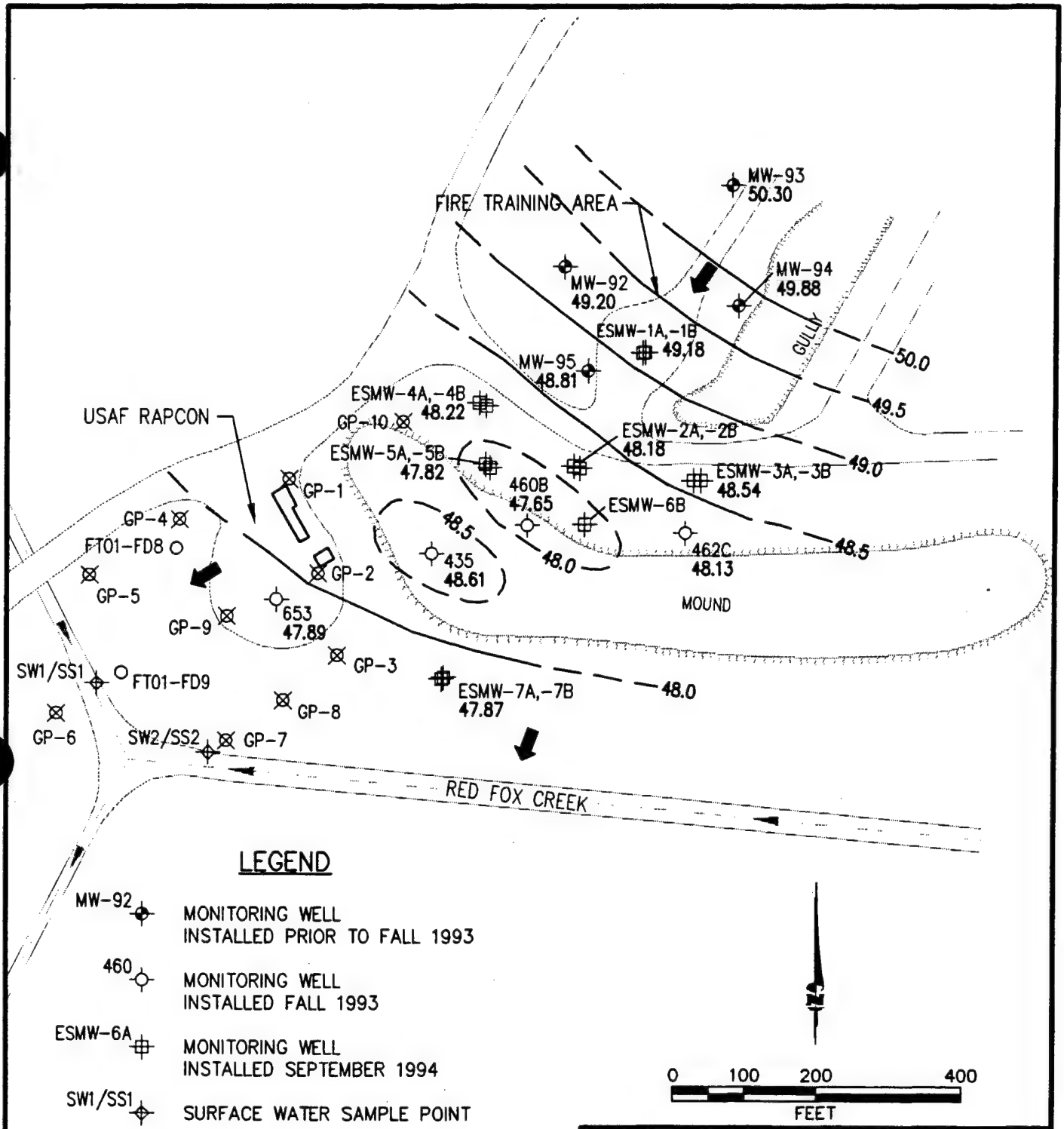
3.4.2.1 Flow Direction and Gradient

On the basis of geologic and hydrogeologic information, the shallow aquifer at Site FT01 is unconfined. Groundwater in the study area flows to the south and southwest, as indicated by groundwater levels observed in September 1994 and July 1995 (Figures 3.5 and 3.6, respectively). Depths to groundwater vary from 0 feet bgs along Red Fox Creek to 20 feet bgs at the mound separating the fire training pit from Red Fox Creek (Table 3.1). The average depth to groundwater in the vicinity of the fire training pit is 11 feet bgs. Gradients are approximately 0.005 foot per foot (ft/ft) in the vicinity of the fire training pit and decrease to approximately 0.0008 ft/ft near the RAPCON site. The general groundwater flow direction is to the southwest based on relative groundwater table elevations measured in monitoring wells located in the study area, and monitoring wells located approximately 1,500 feet south. that are associated with Landfill No. 2. Vertical groundwater gradients are low and varied between a downward gradient of 0.004 ft/ft (ESMW-4A and B) and a vertical gradient of 0.005 ft/ft (ESMW-5A and B).

Irregularities in the surface of the groundwater table were apparent in the vicinity of the wooded mound south of the fire training area. These irregularities appear to mirror the surface topography in this portion of the site. Groundwater mounding was observed at monitoring well 435, located on the wooded mound separating Site FT01 from the RAPCON site, in September 1994 and July 1995 (Figures 3.5 and 3.6, respectively). A depression in the groundwater table was observed at monitoring wells ESMW-5A and ESMW-6B, which are located north of the wooded mound in a low topographic area.

3.4.2.2 Hydraulic Conductivity

Slug tests in the shallow A aquifer were performed in early studies in the KSA area by CH_2M Hill (1990). Recorded hydraulic conductivities from these tests varied from 0.0104 foot per minute (ft/min) to 0.9513 ft/min, with an average value of 0.2431 ft/min. These values represent a generalized range for the fire training area as well as 10 other IRP sites. Hydraulic conductivity was estimated in 1994 at two wells installed by Parsons ES using rising head and falling head slug tests, as described in Section 2. Hydraulic conductivities measured at ESMW-1A were 0.0425 and 0.0669 ft/min (average of 0.0547 ft/min). Hydraulic conductivities measured at monitoring well ESMW-2A were 0.0273 and 0.0277 ft/min (average of 0.02746 ft/min). The average hydraulic conductivity from wells ESMW-1A and ESMW-2A is 0.0411 ft/min. This average hydraulic conductivity value is within the lower range of those measured by CH_2M Hill (1990), and is typical of fine- to medium-grained sandy soils (Freeze and Cherry, 1979).



LEGEND

- MW-92 — MONITORING WELL INSTALLED PRIOR TO FALL 1993
- 460 — MONITORING WELL INSTALLED FALL 1993
- ESMW-6A — MONITORING WELL INSTALLED SEPTEMBER 1994
- SW1/SS1 — SURFACE WATER SAMPLE POINT
- FT01-FD8 — MONITORING WELL INSTALLED OCTOBER 1994
- GP-1 — TEMPORARY MONITORING POINT INSTALLED JULY 1995
- ESTIMATED GROUNDWATER FLOW DIRECTION
- LINE OF EQUAL GROUNDWATER ELEVATION (FEET ABOVE MEAN LOWER LOW WATER), DASHED WHERE INFERRED

0 100 200 400
FEET

FIGURE 3.5

GROUNDWATER ELEVATIONS (SEPTEMBER 1994)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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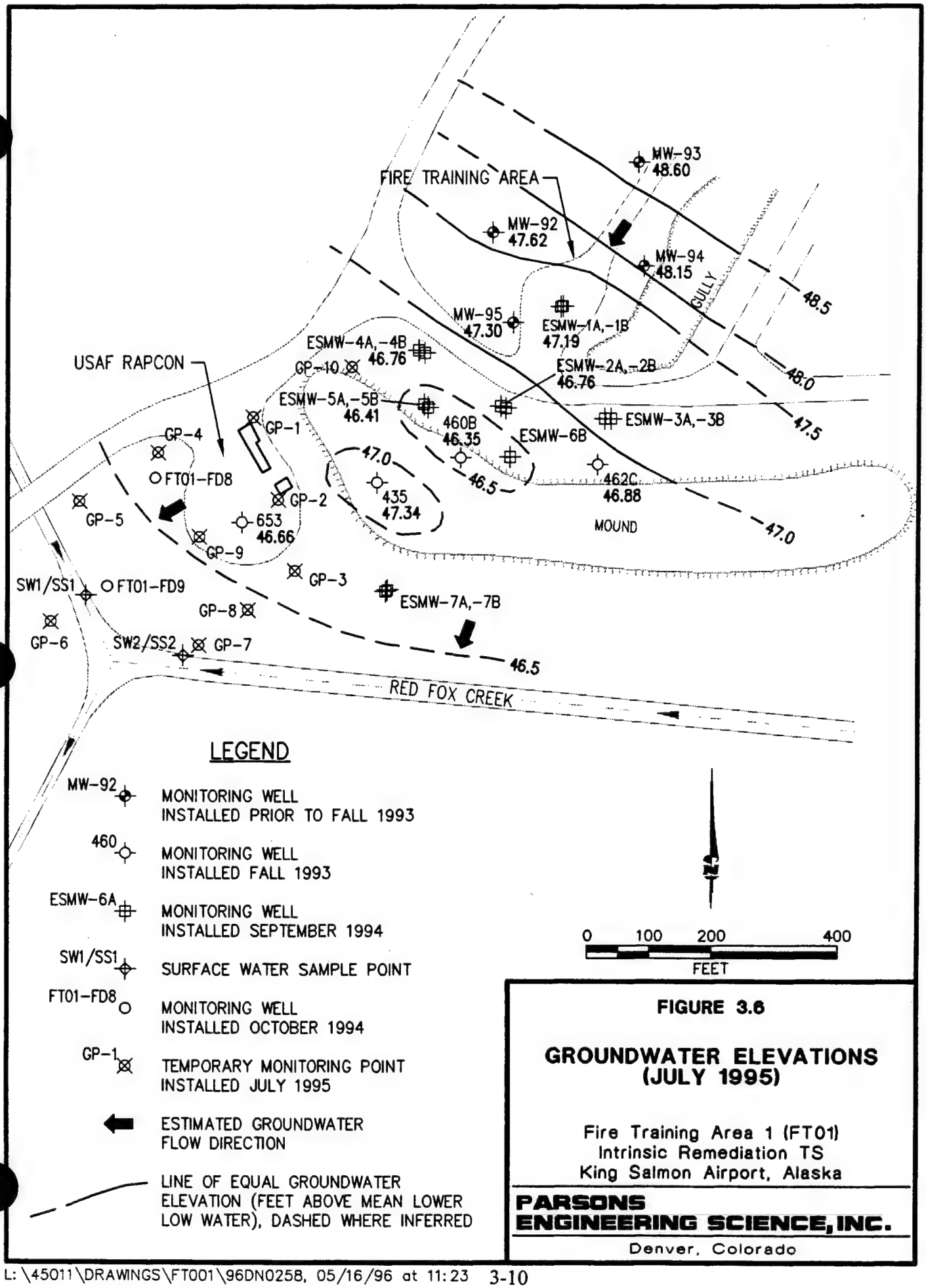

FIGURE 3.6

GROUNDWATER ELEVATIONS (JULY 1995)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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TABLE 3.1
WATER LEVEL ELEVATION DATA
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Well Designation	Sampling Date	Datum Elevation (mllw)[a/]	Ground Elevation (mllw)	Screen Interval Top (ft bgs)	Screen Interval Bottom (ft bgs)	Total Depth to Water (ft bgs)[b/]	Total Depth to Water (ft btoc)[c/]	Elevation of Water Table (mllw)
435	9/94	66.84	64.5	15.0	25.0	15.88	18.23	48.61
435	7/95	66.84	64.5	15.0	25.0	17.15	19.50	47.34
653	9/94	60.00	57.2	9.5	19.5	9.30	12.11	47.89
653	7/95	60.00	57.2	9.5	19.5	10.53	13.34	46.66
460B	9/94	62.07	59.2	9.0	19.0	11.54	14.42	47.65
460B	7/95	62.07	59.2	9.0	19.0	12.84	15.72	46.35
462C	9/94	53.56	52.1	4.0	14.0	3.96	5.43	48.13
462C	7/95	53.56	52.1	4.0	14.0	5.21	6.68	46.88
ESMW-1A	9/94	62.89	60.5	13.0	18.0	11.31	13.71	49.18
ESMW-1A	7/95	62.89	60.5	13.0	18.0	13.30	15.70	47.19
ESMW-1B	9/94	62.98	60.5	31.1	38.1	11.32	13.81	49.17
ESMW-2A	9/94	63.80	61.1	13.0	18.0	12.91	15.62	48.18
ESMW-2A	7/95	63.80	61.1	13.0	18.0	14.33	17.04	46.76
ESMW-2B	9/94	63.77	61.1	35.0	40.0	12.92	15.60	48.17
ESMW-2B	7/95	63.77	61.1	35.0	40.0	14.32	17.00	46.77
ESMW-3A	9/94	62.85	60.5	12.0	17.0	11.95	14.31	48.54
ESMW-3B	9/94	63.41	60.5	33.2	38.2	11.92	14.84	48.57
ESMW-4A	9/94	63.71	61.0	13.0	18.0	12.77	15.49	48.22
ESMW-4A	7/95	63.71	61.0	13.0	18.0	14.23	16.95	46.76
ESMW-4B	9/94	63.64	61.0	32.0	37.0	12.83	15.48	48.16
ESMW-4B	7/95	63.64	61.0	32.0	37.0	14.28	16.93	46.71
ESMW-5A	9/94	54.57	51.9	4.0	9.0	4.07	6.75	47.82
ESMW-5A	7/95	54.57	51.9	4.0	9.0	5.48	8.16	46.41
ESMW-5B	9/94	55.02	51.9	22.1	27.1	4.02	7.15	47.87
ESMW-5B	7/95	55.02	51.9	22.1	27.1	5.41	8.54	46.48
ESMW-6B	9/94	55.70	53.0	23.0	28.0	5.13	7.84	47.86
ESMW-6B	7/95	55.70	53.0	23.0	28.0	6.43	9.14	46.56
ESMW-7A	9/94	60.15	57.1	8.0	13.0	9.22	12.28	47.87
ESMW-7B	9/94	59.69	56.9	25.5	30.5	31.00	11.83	47.86
EMCON-1	7/95	N/A[d/]	N/A	3.0	13.0	N/A	7.98	N/A
EMCON-2	7/95	N/A	N/A	3.0	13.0	N/A	11.71	N/A
MW-92	7/95	65.54	63.9	9.0	29.0	14.69	16.34	49.20
MW-92	7/95	65.54	63.9	9.0	29.0	16.27	17.92	47.62
MW-93	9/94	61.46	59.5	5.0	25.0	9.19	11.16	50.30
MW-93	7/95	61.46	59.5	5.0	25.0	10.89	12.86	48.60
MW-94	9/94	61.27	59.2	6.0	26.0	9.31	11.39	49.88
MW-94	7/95	61.27	59.2	6.0	26.0	11.04	13.12	48.15
MW-95	9/94	61.16	59.2	7.5	27.5	10.38	12.35	48.81
MW-95	7/95	61.16	59.2	7.5	27.5	11.89	13.86	47.30

[a/] ft mllw = Feet above mean lower low water level.

[b/] ft bgs = Feet below ground surface.

[c/] ft btoc = Feet below top of casing.

[d/] N/A = Data not available.

3.4.2.3 Effective Porosity

Because effective porosity data are not available for the study area, accepted literature values for the type of soil comprising the shallow saturated zone were used. The effective porosity of an unconfined aquifer is the porosity of the aquifer minus the specific retention (or the groundwater retained against the force of gravity after a unit volume of an unconfined aquifer is drained). Freeze and Cherry (1979) give a range of porosities for sands of 0.25 to 0.50, whereas the effective porosity for sands ranges from 0.10 to 0.35 (Wiedemeier *et al.*, 1995). The effective porosity for sediments of the shallow saturated zone in the study area was assumed to be 0.25, which is an appropriate value for fine- to medium-grained sands.

3.4.2.4 Advective Groundwater Velocity

The advective velocity of groundwater in the direction parallel to groundwater flow is given by:

$$\bar{v} = \frac{K\,dH}{n_e\,dL}$$

Where: $\bar{v}$ = Average advective groundwater velocity (seepage velocity) [L/T]

K = Hydraulic conductivity [L/T] (0.041 ft/min)

dH/dL = Gradient [L/L] (0.005 to 0.0008 ft/ft)

n_e = Effective porosity (0.25).

Using this relationship in conjunction with site-specific data, the advective groundwater velocity at the study area ranges from 0.00082 to 0.00013 ft/min [69 to 447 feet per year (ft/year)].

3.5 POTENTIAL PATHWAYS AND RECEPTORS

Groundwater migration pathways to potential receptors may include discharge of contaminated groundwater to Red Fox Creek and associated wetland areas, migration and discharge to the Naknek River, or migration of the contaminant plume into downgradient potable and nonpotable water wells. Potential receptors include KSA workers, trespassers using Red Fox Creek and/or the Naknek River, and wildlife/aquatic organisms in and near Red Fox Creek and the associated wetlands.

Groundwater extraction wells installed by the Air Force at KSA are screened in the C-Aquifer (approximately 200 feet bgs) and are not located downgradient of Site FT01. Private off-Base wells in the town of King Salmon are predominantly screened in the B-Aquifer. The potential for downward contaminant migration through the A-Aquitard barrier and contamination of the B-Aquifer is minimal, based on low vertical groundwater gradients (Section 3.4.2.1). Furthermore, the estimated saturated thickness of the surficial aquifer is relatively high (>30 feet) and will enhance the dilution of downward migrating contaminants.

Groundwater from Site FT01 and/or the RAPCON site may ultimately discharge into the Naknek River, which is approximately 4,000 feet to the southwest (5,500 feet downgradient along Red Fox Creek). The potential exists for surface water contamination from the study area in Red Fox Creek and the wetlands along the creek.

SECTION 4

NATURE AND EXTENT OF CONTAMINATION AND SOIL AND GROUNDWATER GEOCHEMISTRY

4.1 SOURCE OF CONTAMINATION

The contamination at Site FT01 appears to have been sourced at the former fire training pit and surroundings (Figure 1.4). It is suspected that uncombusted fuels, solvents, oils, and fire retardant chemicals were released directly into the unlined pit and onto soils surrounding the pit since the beginning of fire training exercises in 1980 (ES, 1985). An AST that was formerly used to store flammable liquids was removed from the site at an unknown date (SAIC, 1993b). Based on piping from the surface of the pit to the vicinity of MW-92, the suspected location of the tank was near MW-92. In late June through early August 1995, grossly contaminated soils from the fire training pit were excavated, and the pit was backfilled with clean soil (EMCON, 1995b).

An AST associated with the former RAPCON site located southwest of the fire training area was reportedly removed at an unknown date (SAIC, 1993b). This AST may have had a 2,000-gallon capacity, and may have been associated with the northern service building located at the site (Figure 2.1). However, the exact size, contents, and location of the former RAPCON AST is unknown. Unconfirmed information suggests that a former 500-gallon underground storage tank (UST) associated with a demolished building (possibly building 560) also was located at the site (Environmental Management, Inc., 1996). The former UST was reportedly located near the central or southwestern portion of the gravel cul-de-sac at the RAPCON site (Figure 2.1) (EMCON, 1996a). Documentation recording releases from the UST or AST at the RAPCON site was not located; however, soils surrounding the former 500-gallon UST location are believed to be contaminated based on observed groundwater contaminant concentrations in this area (Section 4.5.1). These soils may be a continuing source of soil and groundwater contamination.

No free-product has been detected in site monitoring wells; however, a 0.25-inch layer of free product was encountered and removed from the groundwater surface during excavation activities at the fire-training pit. Furthermore, apparent hydrocarbon sheens on surface water of Red Fox Creek, and stressed vegetation along the creek bank were observed during the installation of monitoring well FT01-FD9 (Figure 2.1) in 1994 (EMCON, 1996b).

4.2 SOIL QUALITY

4.2.1 Residual LNAPL Contamination

Residual LNAPL is defined as the LNAPL that is trapped in the aquifer by the processes of cohesion and capillarity, and therefore will not flow within the aquifer and will not flow from the aquifer matrix into a well under the influence of gravity. At the study area, the residual LNAPL consists primarily of fuel hydrocarbons released from fire training exercises. Numerous site characterization events conducted in support of the Base IRP and as part of this intrinsic remediation TS have attempted to define the extent of residual LNAPL contamination. These results are summarized below.

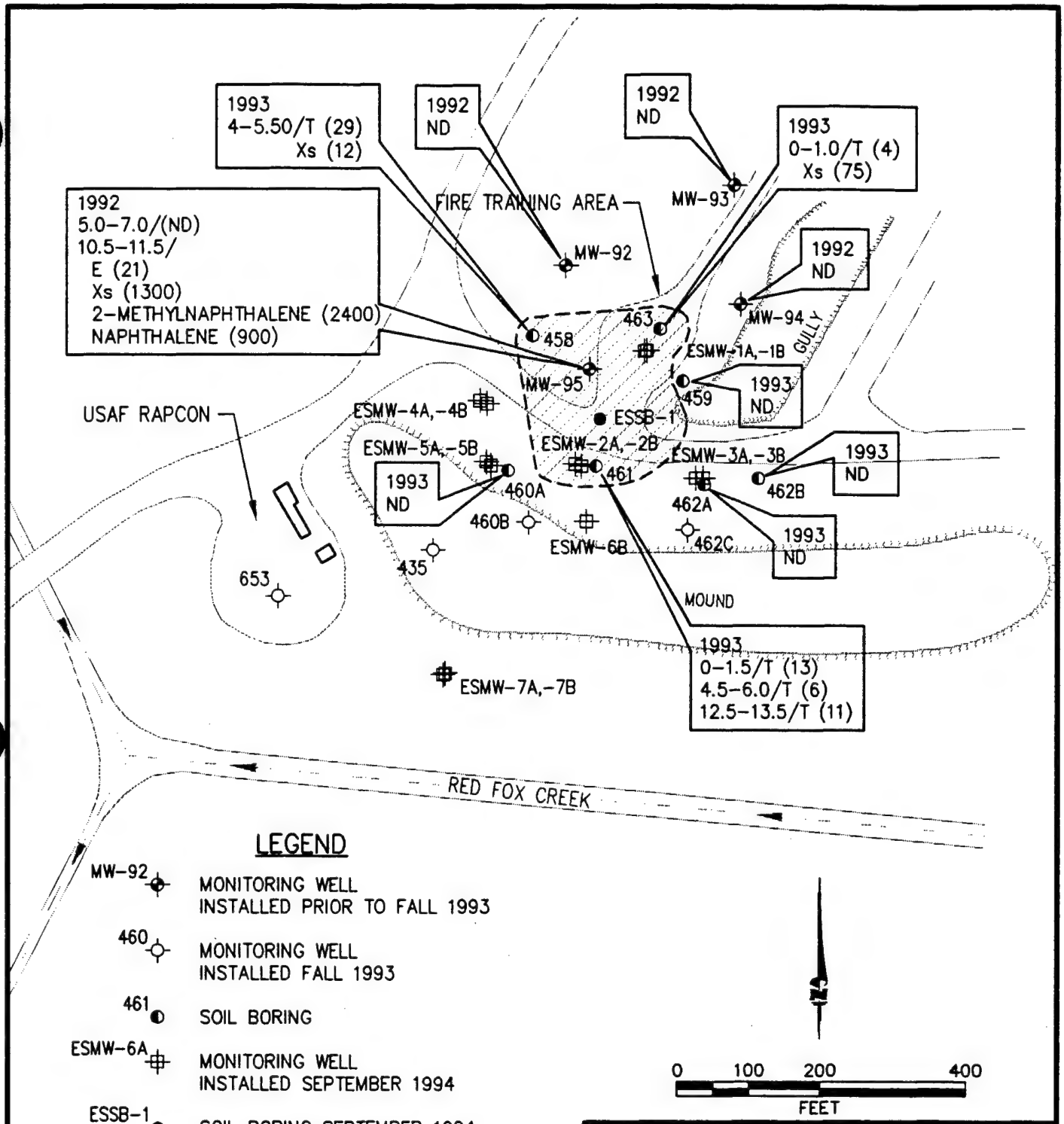
4.2.1.1 Soil Gas Data

Thirty-eight soil gas samples were collected at Site FT01 to supplement the IRP RI and to confirm suspected contaminant source and pathways at the fire training area (SAIC, 1993a). Results of the soil gas study indicated the presence of BTEX and other VOCs at four locations within and surrounding the fire training pit. Maximum VOC concentrations were detected near the center of the fire training pit, at 280,000 parts per billion by volume (ppbv) methylethyl ketone (MEK); 77,000 ppbv benzene; 69,000 ppbv total xylenes; 57,000 ppbv toluene; 49,000 ppbv ethylbenzene; 520 ppbv trichloroethene TCE; and 890 ppbv 1,1-dichloroethane (DCA). Other VOCs at lower concentrations (not exceeding 6,800 ppbv) were detected approximately 100 feet northwest of the fire training pit and 90 feet southwest, near monitoring well MW-95.

4.2.1.2 Soil Contamination

Prior to the installation of monitoring wells MW-92 to MW-95 in September 1992, nine subsurface soil samples were collected at various depths from the monitoring well boreholes (SAIC, 1993a). Soil analytical results revealed the presence of VOCs and semivolatile organic compounds (SVOCs) in only one of the soil samples collected. This sample was collected at a depth of 10.5 to 11.5 feet bgs at MW-95, which is located approximately 100 feet southwest of the fire training pit (Figure 4.1). In this sample, ethylbenzene was detected at a concentration of 21.0 micrograms per kilogram (µg/kg); xylenes at 1,300 µg/kg; 2-methylnapthalene at 2,400 µg/kg; and naphthalene at 900 µg/kg. Diesel-range organics (DROs) were also detected at 360,000 µg/kg in this sample (SAIC, 1993a). Figure 4.1 illustrates VOC and SVOC concentrations in 1992 and 1993.

Additional soil sampling was performed by EMCON (1994a) in October 1993 to supplement and verify previous RI work performed by SAIC. Nineteen soil samples were collected from 10 boreholes (458, 459, 460A, 461, 462A, 462B, 463, 460B, 462C, and 435). Soil analytical data indicated the presence of VOC contamination in three subsurface soil samples from soil borings 458, 461, and 463 (Figure 4.1). Benzene was not detected in any of the soil samples. Toluene was detected in soil borings 458, 461, and 463 at concentrations ranging from 4 µg/kg to 29 µg/kg. Total xylenes were detected at 12 µg/kg and 75 µg/kg in soil boring 458 and 463, respectively. DROs were detected at the site in 12 of the 19 soil samples at concentrations ranging from 10 mg/kg at soil boring 459 to 5,930 milligrams per kilogram (mg/kg) in soil boring 463. Figure 4.2 presents the highest detected DRO concentrations. The highest DRO concentrations were



SOURCE: SAIC, 1993b, EMCON 1994a

FIGURE 4.1

VOC AND SVOC CONCENTRATIONS IN SOIL (1992 and 1993)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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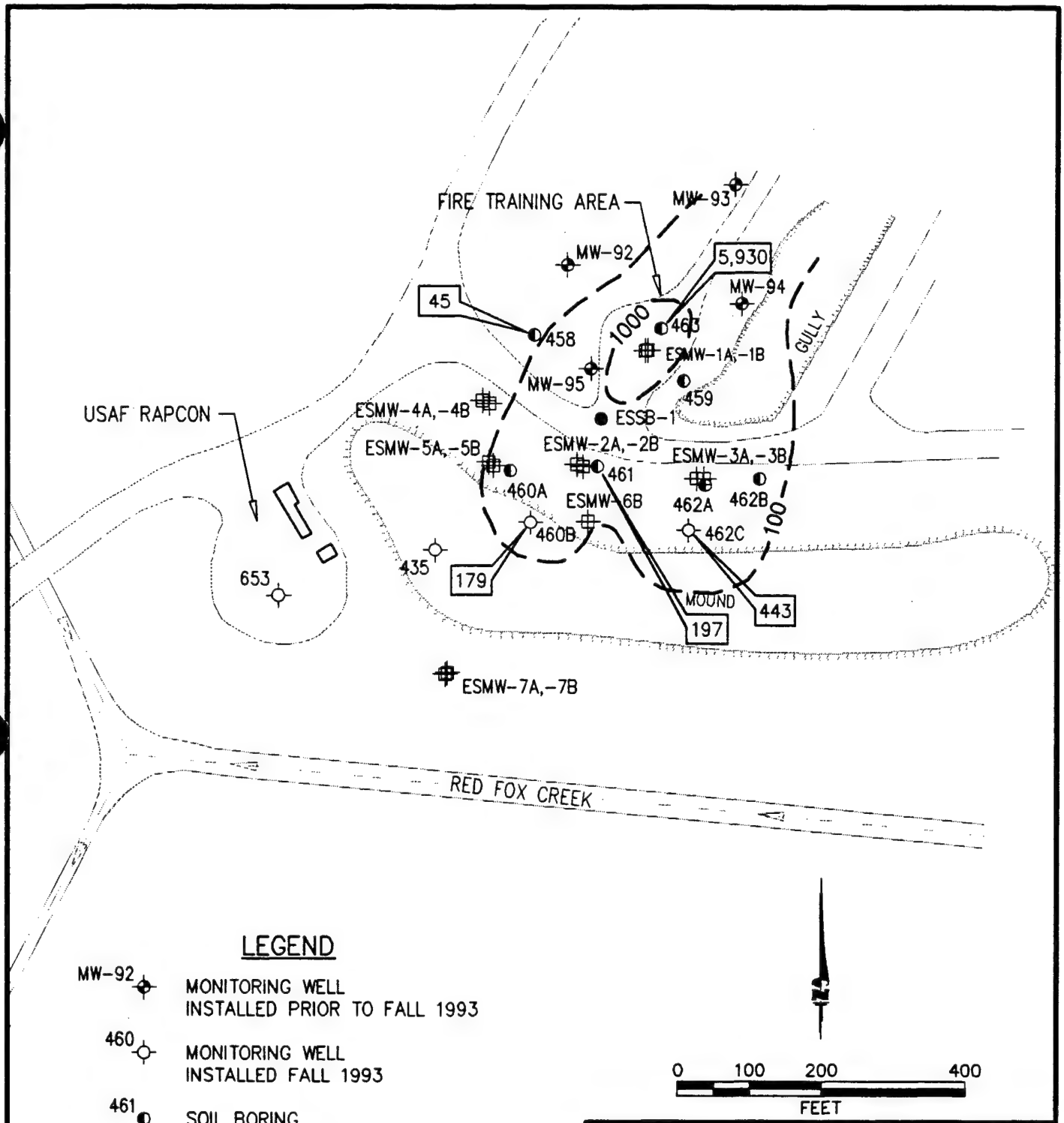


SOURCE: EMCON, 1994a.

FIGURE 4.2

SOIL DRO CONCENTRATIONS 0-1.5 feet bgs (1993)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

measured in samples collected near the ground surface. Total petroleum hydrocarbons (TPH) also were detected at elevated concentrations in 10 of the 19 soil samples, ranging from 21 mg/kg at soil boring 459 to 13,000 mg/kg in soil boring 463. Dioxin compounds were measured at soil boring 463 at a maximum concentration of 12.0 µg/kg (octachlorodibenzo-p-dioxin). Based on these results, it appears that the majority of the soil contamination was confined to the fire training pit and soils located south of the fire training pit in the vicinity of the access road and entryway to the fire training pit. The highest soil contamination was consistently observed in samples collected from the top 1 foot of soil.

In May 1995, soil samples were collected from the borehole for well 653 at the RAPCON site (EMCON, 1994b). Soil samples were analyzed for DRO, TPH, and VOC compounds. Complete VOC data were not available at the time of this report. However, maximum concentrations of 9,700 mg/kg TPH and 5,480 mg/kg DRO were detected at 10 feet bgs. Concentrations of DRO and TPH were detected in all soil samples collected from 5.5 to 16.5 feet bgs, and suggest the presence of previously unidentified source area at the site.

In September 1994, Parsons ES collected 11 soil samples from 6 boreholes at Site FT01 as part of this TS. With the exception of ESSB-1, all soil samples were collected from soil boreholes completed as deep monitoring wells screened in the lower portion of the shallow aquifer (e.g., ESMW-1B, ESMW-2B, ESMW-3B, ESMW-5B, and ESMW-7B). The soil samples were analyzed for BTEX, trimethylbenzene (TMB) isomers, and TPH (normalized for JP-4). Table 4.1 summarizes the results of this soil sampling event. BTEX were detected at ESSB-1, ESMW-1B and ESMW-7B. The maximum BTEX concentration of 138 mg/kg was detected in the 10- to 12-foot-bgs sample from ESMW-1B. Concentrations of TPH were detected in every soil sample collected at concentrations ranging from 0.03 mg/kg to 2,130 mg/kg. Low concentrations of the chlorinated solvents PCE and TCE were detected at both boreholes near the fire training pit where BTEX concentrations were detected. PCE was detected only from 10.0 to 12.0 feet bgs at ESMW-1A (0.129 mg/kg), and TCE was detected only from 14.5 to 16.0 feet bgs at ESSB-1 (0.019 mg/kg) (Figure 4.3).

From June 27 through August 1, 1995, the fire training pit was excavated and refilled with clean backfill (EMCON, 1995b). Approximately 2,025 cy of soil were removed from an excavation with a 140-foot diameter and a depth of approximately 12 feet (reaching groundwater). A 0.25-inch layer of mobile LNAPL was observed in the excavation was skimmed from the water surface using sorbent boom materials. Soil samples were collected from the sidewalls of the excavation during progressive removal of soils and analyzed for DRO, gasoline-range organics (GRO), and TPH. Maximum concentrations of soil contamination collected from sidewall samples during the excavation were 115 mg/kg GRO, 309 mg/kg DRO, and 574 mg/kg TPH. Higher concentrations of fuel hydrocarbons were detected in the bottom of the excavation (46,000 mg/kg GRO, 1,100 mg/kg of DRO, 2,400 mg/kg TPH, 32 mg/kg benzene, 270 mg/kg toluene, 83 mg/kg ethylbenzene, and 380 mg/kg xylene). Elevated fuel hydrocarbon concentrations near the bottom of the excavation relative to the sidewalls is likely due to mobile LNAPL smearing through the capillary zone. The majority of soil

TABLE 4.1
FUEL HYDROCARBON COMPOUNDS DETECTED IN SOIL
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

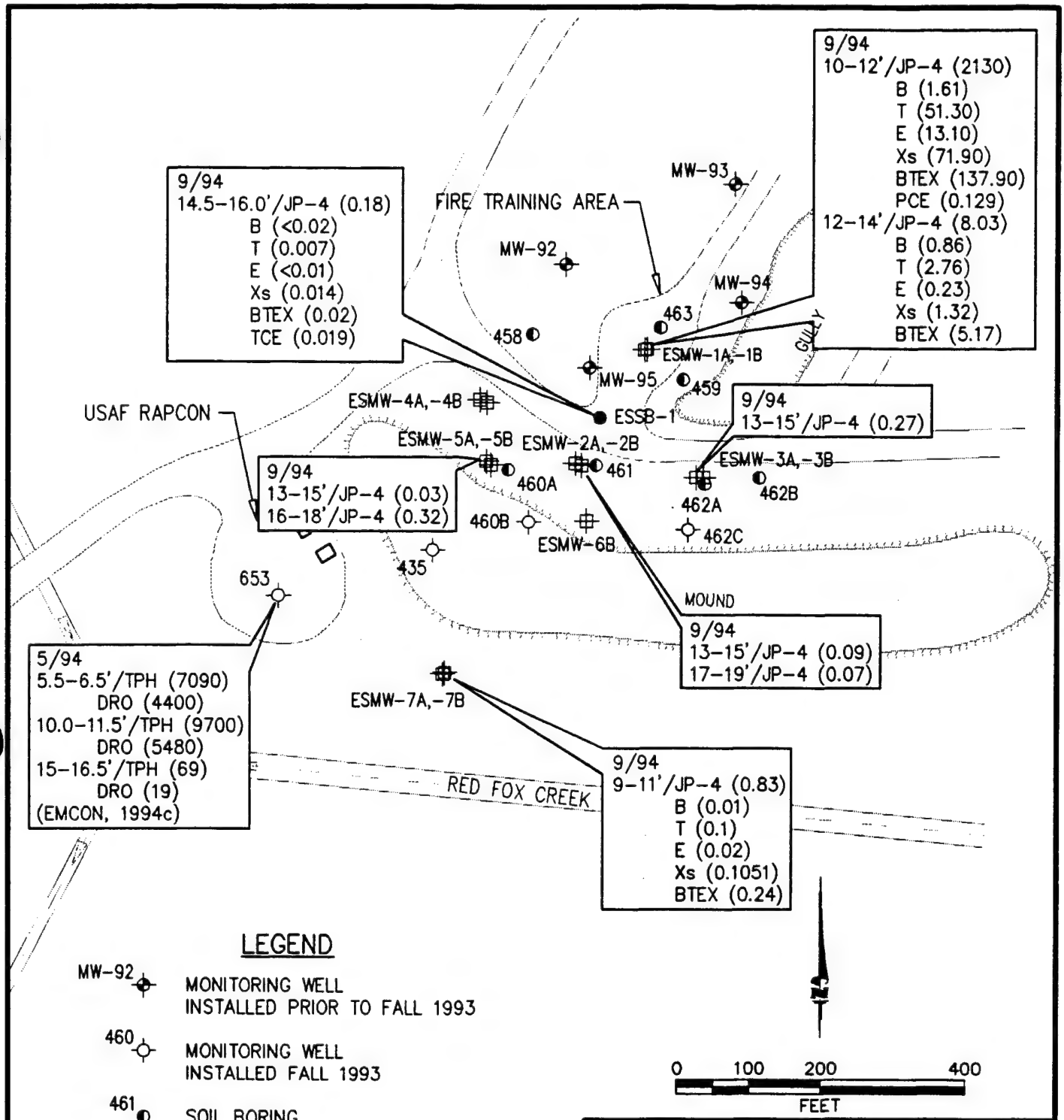
Sample Location	Sample Date	Sample Depth (ft bgs)	JP-4[a/] (mg/kg)	Fuel Carbon (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	p-xylene (mg/kg)	m-Xylene (mg/kg)	o-Xylene (mg/kg)	Total Xylenes (mg/kg)	Total BTEX (mg/kg)	1,3,5-TMB (mg/kg)	1,2,4-TMB (mg/kg)	1,2,3-TMB (mg/kg)
ESSB-1	10/94	14.5-16	1.80E-01	1.50E-01	<0.02	7.17E-03	<0.02	<0.02	7.94E-03	6.15E-03	1.41E-02	2.13E-02	<0.02	6.53E-03	<0.02
ESMW-1B	10/94	10-12	2130	1810	1.61E+00	5.13E+01	1.31E+01	1.40E+01	4.03E+01	1.76E+01	7.19E+01	1.38E+02	1.09E+01	2.31E+01	8.91E+00
ESMW-1B	10/94	12-14	8.03	6.83	8.62E-01	2.76E+00	2.26E-01	2.54E-01	6.81E-01	3.85E-01	1.32E+00	5.17E+00	8.09E-02	2.40E-01	1.20E-01
ESMW-2B	10/94	13-15	0.09	0.08	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND[b/]	<0.02	<0.02
ESMW-2B	10/94	17-19	0.07	0.06	ND	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND	ND	ND
ESMW-2B	10/94	40-42	0.38	0.33	<0.02	<0.02	ND	ND	ND	ND	ND	<0.02	ND	ND	ND
ESMW-3B	10/94	13-15	0.27	0.23	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND	ND	ND
ESMW-5B	10/94	13-15	0.03	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND	<0.02	<0.02
ESMW-5B	10/94	16-18	0.32	0.27	ND	<0.02	ND	ND	ND	ND	ND	<0.02	ND	ND	ND
ESMW-7B	10/94	NA[c/]	0.83	0.71	1.48E-02	1.06E-01	1.76E-02	2.03E-02	5.54E-02	2.94E-02	1.05E-01	2.44E-01	1.15E-02	2.88E-02	1.24E-02
ESMW-7B	10/94	11-13	0.13	0.11	ND	<0.02	ND	ND	ND	ND	ND	<0.02	ND	ND	ND
SS1	7/95	Sediment	NA	NA	1.22E+00	4.43E+00	9.73E+00	1.19E+01	2.20E+01	1.03E+01	4.42E+01	5.96E+01	1.19E+00	3.29E+00	8.69E-01
SS2	7/95	Sediment	NA	NA	ND	BLQ[d/]	ND	ND	ND	ND	ND	ND	ND	ND	ND

[a/] JP-4 = JP-4 Jet fuel

[b/] ND = Not detected

[c/] NA = Not available

[d/] BLQ = Below Limit of Quantitation; 0.05 µg/mL



LEGEND

- MW–92 — MONITORING WELL INSTALLED PRIOR TO FALL 1993
- 460 — MONITORING WELL INSTALLED FALL 1993
- 461 — SOIL BORING
- ESMW–6A — MONITORING WELL INSTALLED SEPTEMBER 1994
- ESSB–1 — SOIL BORING SEPTEMBER 1994
- 10–12'/JP–4 (ND) — SAMPLE DEPTH–FEET BELOW GROUND SURFACE/ANALYTE CONCENTRATION (mg/kg) ND = NOT DETECTED

FIGURE 4.3

TOTAL DRO, JP-4, TPH, BTEX, TCE AND PCE CONCENTRATIONS IN SOIL (1994)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

contamination was believed to have been removed during the excavation process (EMCON, 1995b).

On the basis of available soil analytical results, the highest concentrations of soil contamination appear to have been within the fire training pit. However, VOCs and high concentrations of DROs also were detected south of the pit as far as monitoring well 460B (Figure 4.2). Historic detections of fuel hydrocarbons north of the fire training pit and at locations south of the pit near boreholes 461 and 460A were relatively low. Furthermore, no concentrations of VOC or TPH were detected in soil samples from monitoring well locations ESMW-4B, ESMW-2B, and ESMW-3B, which suggests that significant contaminant mass had not migrated in soils beyond the access road south of the fire training pit. Significant concentrations of TPH and DRO in soils from borehole 653 suggests that a secondary source of contamination may exist at the former RAPCON site. Base personnel have indicated that a former AST was removed from this area (EMCON, 1994c).

4.2.2 Total Organic Carbon

TOC concentrations are used to estimate the amount of organic matter sorbed to soil particles or trapped in the interstitial passages of a soil matrix. The TOC concentration in the saturated zone is an important parameter used to estimate the amount of organic contaminant mass that could potentially be sorbed to the aquifer matrix. Sorption results in retardation of the dissolved contaminant plume relative to the average advective groundwater velocity.

The percent soil TOC was measured in five saturated soil samples collected at the capillary fringe during monitoring well installation (Table 4.2). The average TOC concentrations for all soil samples was 0.019 percent. The average TOC concentrations from soil sampling locations ESMW-3B and ESMW-7B, which are peripheral to the majority of soil contamination, was 0.017 percent. These TOC values are indicative of soils containing little organic carbon.

4.3 SEDIMENT AND SURFACE WATER QUALITY

4.3.1 Sediment Data

Two samples were collected in July 1995 from the upper 4 inches of Red Fox Creek sediments and analyzed for BTEX and TMB compounds (Figure 2.2). The results of sediment sampling are summarized in Table 4.1. The two samples were collected along the suspected segment of contaminated groundwater discharge (SS1) and upgradient of the contaminated discharge segment (SS2) (Figure 2.2). Sediment sample SS1 (downgradient from FT01-FD9) contained 59.6 mg/kg of total BTEX and 1.2 mg/kg of benzene. TMB compounds ranged in concentration from 0.87 to 3.29 mg/kg. No BTEX or TMBs were measured in sample SS2. These sediment quality data suggest that hydrocarbon contamination from Site FT01 or the RAPCON site is impacting Red Fox Creek.

TABLE 4.2
SOIL TOC RESULTS
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Sample Depth (feet bgs)	Soil Filt %TOC[a/]	Solids %TOC	Total Soil %TOC	Mean Soil %TOC
ES-MW1B	9/94	10-12	0.009	0.028	0.037	
ES-MW1B(D)[b/]	9/94	10-12	0.004	0.031	0.035	0.036
ES-MW1B	9/94	12-14	0.002	0.016	0.018	
ES-MW1B(D)	9/94	12-14	0.002	0.012	0.014	0.016
ES-MW2B	9/94	13-15	0.002	0.021	0.023	
ES-MW2B(D)	9/94	13-15	0.002	0.021	0.021	0.022
ES-MW2B	9/94	17-19	<0.001	0.012	0.012	
ES-MW2B(D)	9/94	17-19	0.002	0.016	0.018	0.015
ES-MW2B	9/94	40-42	<0.001	0.018	0.018	
ES-MW2B(D)	9/94	40-42	<0.001	0.016	0.016	0.017
ES-MW3B	9/94	13-15	0.002	0.015	0.017	
ES-MW3B(D)	9/94	13-15	0.002	0.016	0.018	0.018
ES-MW5B	9/94	13-15	<0.001	0.015	0.015	
ES-MW5B(D)	9/94	13-15	0.002	0.015	0.017	0.016
ES-MW5B	9/94	16-18	<0.001	0.017	0.017	
ES-MW5B(D)	9/94	16-18	<0.001	0.016	0.016	0.017
ES-MW7B	9/94	11-13	0.002	0.014	0.016	
ES-MW7B(D)	9/94	11-13	0.002	0.014	0.016	0.016
SS01	7/95	Sediment	0.159	0.728	0.887	
SS01(D)	7/95	Sediment	0.168	0.830	0.998	0.943
SS02	7/95	Sediment	0.055	0.489	0.544	
SS02(D)	7/95	Sediment	0.061	0.502	0.563	0.554

[a/] TOC = Total Organic Carbon

[b/] D = Duplicate

4.3.2 Surface Water Quality

A surface water sample was collected from Red Fox Creek in July 1994 at sampling location SW625 which was located approximately 70 feet southwest of monitoring well FT01-FD9 (EMCON, 1994d). The sample was analyzed by USEPA Method M8100 and a low concentration of 1.4 mg/L DRO was detected. Two surface water samples were collected from Red Fox Creek (Figure 2.2) during sediment sampling in July 1995, and analyzed for BTEX, TMBs, and naphthalene. Analytical results are presented in Tables 4.3 and 4.4. The highest BTEX concentration of 352 micrograms per liter (µg/L) was measured at surface water sampling location SW1 (Figure 2.2); the benzene component contributed 94.8 µg/L to the total concentration. Total BTEX and benzene exceeded the state water quality standards of 10 µg/L for total aromatics (BTEX) and 5 µg/L for benzene, respectively. The surface water sample also contained concentrations of naphthalene (21.6 µg/L), total fuel carbon (772 µg/L), and individual isomers of TMB and tetramethylbenzene (TEMB) (8.0 and 24.7 µg/L, respectively). Lower concentrations of fuel hydrocarbons were detected at surface water sampling location SW2, with total BTEX detected at a concentration of 8.3 µg/L. At a concentration of 4.8 µg/L, benzene contributed over half of the total BTEX concentration at this location. Total fuel carbon was detected at a concentration of 7.6 µg/L. Naphthalene, TMB, and TEMB were not detected at SW2.

The occurrence of fuel hydrocarbon contamination at SW1 suggests that the water quality in Red Fox Creek has been impacted by site contamination. As suggested by low fuel hydrocarbon concentrations in the upstream surface water sample, SW2, a small fraction of observed surface water contamination may be migrating with the creek flow from upstream of the study area. However, the increase in fuel hydrocarbon concentrations from SW2 to SW1 suggests that much of the observed surface water contamination at SW1 results from contaminated groundwater discharging from the study area.

4.4 GROUNDWATER CHEMISTRY

Three lines of evidence can be used to document the occurrence of natural attenuation: 1) documented loss of contaminant mass at the field scale; 2) geochemical evidence; and 3) microcosm studies. The first two lines of evidence (geochemical evidence and documented loss of contaminants) are used herein to support the occurrence of natural attenuation at the study area, as described in the following sections. Because these two lines of evidence strongly suggest that natural attenuation is occurring at this site, a microcosm study was not deemed necessary.

4.4.1 Groundwater Contamination

Several groundwater sampling events conducted since 1992 have indicated the presence of fuel hydrocarbon contamination in the shallow groundwater at Site FT01. A total of three sampling events occurred prior to the September 1994 sampling event conducted by Parsons ES. An initial assessment of groundwater quality was conducted in October 1992 at monitoring wells MW-92 through MW-95 by analyzing for VOCs, SVOCs, DRO, and metals (SAIC, 1993a). Concentrations of DRO were detected in

TABLE 4.3
FUEL HYDROCARBON COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Sample Location	Date	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	TPH (as Fuel Carbon)[a] (µg/L)	Naphthalene (µg/L)
ESMW-1A	9/94	1050.0	6470.0	358.0	398.0	1170.0	690.0	2258.0	10136.0	10100.0	NA
ESMW-1A	7/95	796.0	5400.0	399.0	371.0	1030.0	619.0	2020.0	8615.0	8980.0	69.0
ESMW-1B	9/94	5.6	59.1	20.9	28.9	87.2	36.6	152.7	238.3	1850.0	NA
ESMW-1B	7/95	<1	1.2	ND	ND	<1	<1	<2	1.2	4.8	<10
ESMW-2A	9/94	ND	9.0	<1	<1	2.5	1.4	3.9	12.9	12.1	NA
ESMW-2A	7/95	ND	0.9	ND	ND	<1	ND	<1	0.9	1.2	ND
ESMW-2B	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
ESMW-2B	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ESMW-3A	9/94	0.9	13.0	<1	1.0	2.7	1.5	5.2	19.1	17.5	NA
ESMW-3A	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ESMW-3B	9/94	ND	<1	ND	<1	<1	ND	<2	<3	<1	NA
ESMW-4A	9/94	ND	3.0	ND	ND	1.3	<1	1.3	4.3	4.6	NA
ESMW-4A	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ESMW-4B	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
ESMW-5A	9/94	45.5	8.1	38.5	165.0	139.0	318.0	622.0	714.1	1270.0	NA
ESMW-5A	7/95	14.3	16.8	7.6	20.4	11.6	14.8	46.8	85.5	275.0	21.3
ESMW-5B	9/94	ND	ND	0.9	ND	<1	ND	<1	0.9	27.4	NA
ESMW-5B	7/95	<1	ND	0.9	ND	ND	ND	ND	0.9	1.3	ND
ESMW-6B	9/94	ND	1.7	ND	ND	<1	ND	<1	1.7	2.2	NA
ESMW-6B	7/95	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND
ESMW-7A	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
ESMW-7B	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
FT01-FD9	7/95	319.0	755.0	456.0	448.0	1130.0	698.0	2276.0	3806.0	6680.0	230.0

TABLE 4.3 (Continued)
FUEL HYDROCARBON COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Sample Location	Date	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	TPH (as Fuel Carbon)[a/] (µg/L)	Naphthalene (µg/L)
FT01-FD8	7/95	<1	4.1	<1	<1	<1	<1	<3	4.1	5.8	ND
MW-92	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
MW-92	7/95	ND	2.5	ND	ND	<1	ND	<1	2.5	3.2	ND
MW-93	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
MW-93	7/95	<1	5.6	<1	0.9	2.2	1.4	4.5	10.1	20.2	ND
MW-94	9/94	ND	ND	ND	<1	ND	ND	<1	<1	<1	NA
MW-94	7/95	ND	<1	ND	ND	ND	ND	ND	<1	<1	ND
MW-95	9/94	180.0	470.0	32.7	38.8	106.0	66.0	210.8	893.5	876.0	NA
MW-95	7/95	349.0	1010.0	90.3	99.0	290.0	180.0	569.0	2018.3	2240.0	25.4
435	9/94	58.6	7.1	67.6	93.3	138.0	125.0	356.3	489.6	795.0	NA[b/]
435	7/95	28.2	1.4	17.7	31.7	ND[c/]	2.2	33.9	81.2	241.0	13.1
653*	7/94	330.0	1500.0	180.0	870.00**	NA	390.0	1260.0	3270.0	NA	NA
653	7/95	357.0	1420 J	200.0	210.0	559.0	385.0	1154.0	3131.0	4480 J	127.0
460B	9/94	ND	<1	ND	ND	ND	ND	ND	<1	<1	NA
460B	7/95	<1	4.1	<1	<1	<1	<1	<3	4.1	8.0	ND
462C	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
462C	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GP-1	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GP-2	7/95	ND	<1	<1	<1	<1	ND	<2	<4	<1	ND
GP-3	7/95	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GP-4	7/95	<1	1.3	0.9	1.0	2.0	1.3	4.3	6.5	8.5	ND
GP-5	7/95	2.0	4.7	2.9	3.0	7.1	4.5	14.6	24.2	37.3	ND

TABLE 4.3 (Concluded)
FUEL HYDROCARBON COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Sample Location	Date	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	TPH (as Fuel Carbon)[a] (µg/L)	Naphthalene (µg/L)
GP-6	7/95	2.2	1.6	1.0	1.0	2.3	1.5	4.8	9.6	24.7	ND
GP-7	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GP-8	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GP-9	7/95	1050.0	4150 J	706.0	679.0	1760.0	880.0	3319.0	9225.0	12800 J	366.0
GP-10	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-01	7/95	94.8	52.0	44.3	56.6	64.5	40.0	161.1	352.2	772.0	21.6
SW-02	7/95	4.8	3.5	ND	ND	<1	ND	<1	8.3	7.6	<10

[a] Fuel Carbon = TPH (normalized for JP-4) x 0.85

[b] NA = Not analyzed

[c] ND = Not detected.

[d] J = Laboratory estimate

* Reported by EMCON

** Reported as m&p Xylenes

TABLE 4.4
TRACER COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Sample Location	Date	1,3,5-TMB (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	1,2,4,5-TEMB (µg/L)	1,2,3,5-TEMB (µg/L)	1,2,3,4-TEMB (µg/L)
ESMW-1A	10/94	90.9	284.0	180.0	NA	NA	NA
ESMW-1A	7/95	86.1	229.0	133.0	10.7	17.0	19.6
ESMW-1B	10/94	65.7	144.0	81.4	NA	NA	NA
ESMW-1B	7/95	ND	ND	ND	ND	ND	ND
ESMW-2A	10/94	ND	<1	<1	NA	NA	NA
ESMW-2A	7/95	ND	ND	ND	ND	ND	ND
ESMW-2B	10/94	ND	ND	ND	NA	NA	NA
ESMW-2B	7/95	ND	ND	ND	ND	ND	ND
ESMW-3A	10/94	ND	<1	ND	NA	NA	NA
ESMW-3A	7/95	ND	ND	ND	ND	ND	ND
ESMW-3B	10/94	ND	<1	ND	NA	NA	NA
ESMW-4A	10/94	ND	ND	ND	NA	NA	NA
ESMW-4A	7/95	ND	ND	ND	ND	ND	ND
ESMW-4B	10/94	ND	ND	ND	NA	NA	NA
ESMW-5A	10/94	56.5	115.0	91.9	NA	NA	NA
ESMW-5A	7/95	12.2	22.1	11.4	2.7	3.3	4.4
ESMW-5B	10/94	ND	ND	ND	NA	NA	NA
ESMW-5B	7/95	ND	ND	ND	ND	ND	ND
ESMW-6B	10/94	ND	ND	ND	NA	NA	NA
ESMW-6B	7/95	ND	ND	ND	ND	ND	ND
ESMW-7A	10/94	ND	ND	ND	NA	NA	NA
ESMW-7B	10/94	ND	ND	ND	NA	NA	NA
FT01-FD9	10/94	187.0	556.0	209.0	26.8	42.7	60.2
FT01-FD8	10/94	ND	ND	ND	ND	ND	ND
MW-92	10/94	ND	ND	ND	NA	NA	NA
MW-92	7/95	ND	ND	ND	ND	ND	ND
MW-93	10/94	ND	ND	ND	NA	NA	NA
MW-93	7/95	ND	ND	ND	ND	ND	ND
MW-94	10/94	ND	ND	ND	NA	NA	NA
MW-94	7/95	ND	ND	ND	ND	ND	ND
MW-95	10/94	9.4	25.0	14.6	NA	NA	NA
MW-95*	10/94	18.0	46.0	NA	NA	NA	NA
MW-95	7/95	33.2	75.2	43.7	3.6	5.0	6.5
435	10/94	27.9	72.5	41.8	NA[a/]	NA	NA
435	7/95	10.6	23.2	11.0	1.6	2.1	2.4
653*	10/94	290.0	410.0	NA	NA	NA	NA
653	7/95	95.7	272.0	146.0	17.7	27.2	41.5
460B	10/94	ND[b/]	ND	ND	NA	NA	NA
460B	7/95	ND	ND	ND	ND	ND	ND
462C	10/94	ND	ND	ND	NA	NA	NA
462C	7/95	ND	ND	ND	ND	ND	ND
GP-1	7/95	ND	ND	ND	ND	ND	ND
GP-2	7/95	<1	ND	ND	ND	ND	ND
GP-4	7/95	ND	1.0	ND	ND	ND	ND

TABLE 4.4 (Concluded)
TRACER COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

GP-5	7/95	1.1	3.4	1.2	ND	ND	ND
GP-6	7/95	<1	1.1	ND	ND	ND	ND
GP-7	7/95	ND	ND	ND	ND	ND	ND
GP-8	7/95	ND	ND	ND	ND	ND	ND
GP-9	7/95	245.0	795.0	263.0	35.0	55.9	78.5
GP-10	7/95	ND	ND	ND	ND	ND	ND
SW1	7/95	20.5	24.7	16.3	8.0	10.7	15.6
SW2	7/95	ND	ND	ND	ND	ND	ND

[a] NA = Not Anlayzed

[b] ND = Not Detected

* Reported by EMCON

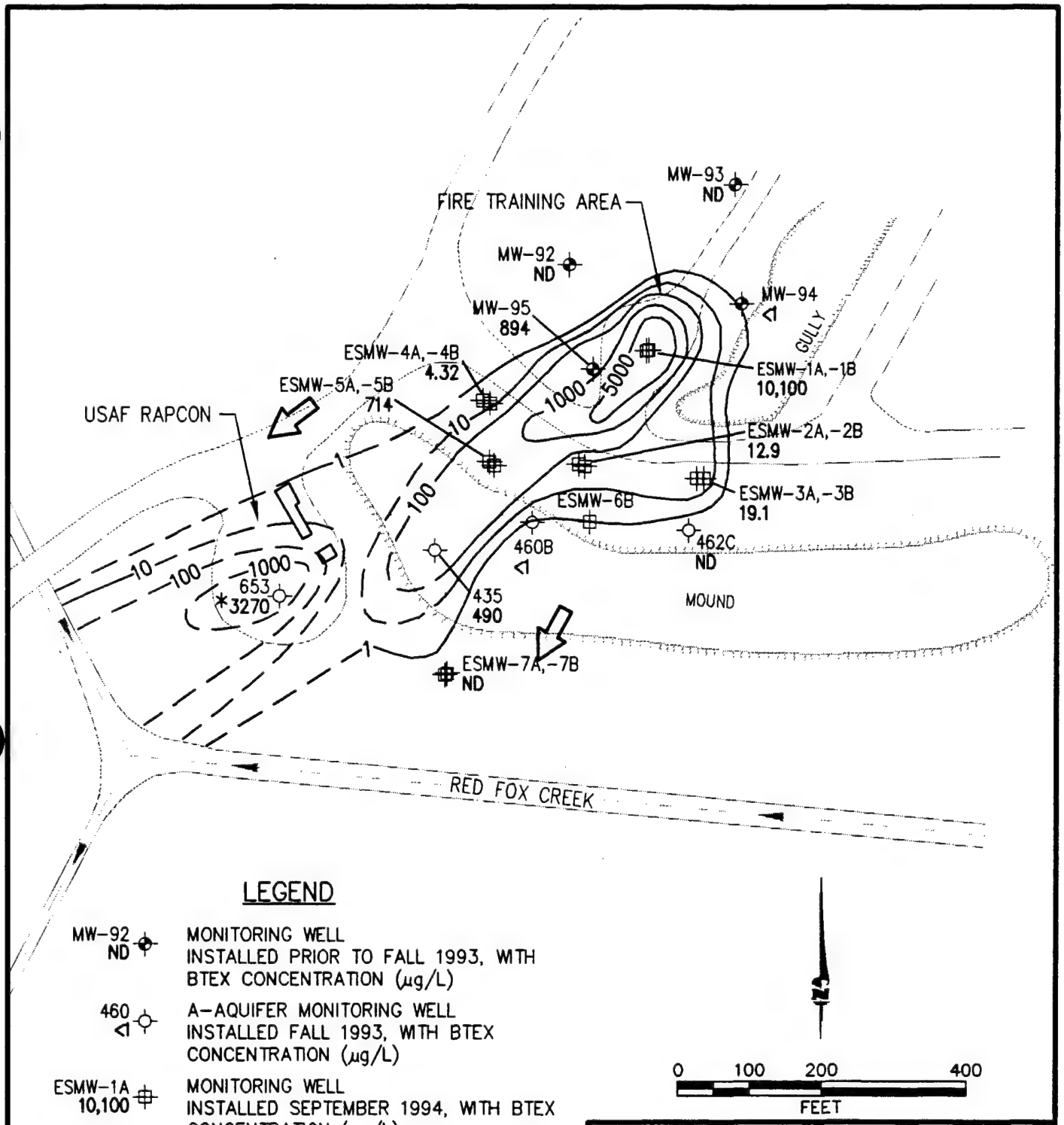
monitoring wells MW-92 and MW-95 at 810 mg/L and 530 mg/L, respectively. VOCs were detected only at monitoring well MW-95, with 3,200 µg/L benzene, 7,200 µg/L toluene, 4,300 µg/L xylenes, and 390 µg/L TCE. During field studies conducted in October 1993, groundwater samples were collected from monitoring wells 460B, 462C, 435, MW-92, MW-93, MW-94, and MW-95 and analyzed for DROs, VOCs, and SVOCs (EMCON, 1994c). VOCs were detected in groundwater monitoring wells MW-92, MW-93, MW-94, MW-95, and 435. Toluene at concentrations ranging from 0.5 to 0.9 µg/L was the only VOC measured in monitoring wells MW-92 through MW-94. Total BTEX concentrations at monitoring wells MW-95 and 435 were 2,117 and 1,918 µg/L, respectively. Monitoring wells MW-95 and 435 contained low levels of chlorinated organics not exceeding 110 µg/L [1,2-DCA, 1,1,1-trichloroethane (TCA), 1,1-DCA, or 1,2,4-trichlorobenzene (TCB)]. DROs were detected in all seven of the groundwater samples at concentrations ranging from 202 µg/L in monitoring well 460 to 71,000 µg/L in well MW-95. It is possible that monitoring well MW-95 contained emulsified product that resulted in a high DRO concentration; however, no mobile LNAPL has been recorded in any available report at any site monitoring well.

Groundwater monitoring wells 460B, 462C, MW-92, and MW-95 were resampled for VOCs (USEPA Methods SW8260) in July 1994 (EMCON, 1995a). Monitoring well 653 was sampled during a separate field event in May 1994 (EMCON, 1995b). With the exception of a low concentration of 1,1,1-TCA (2.7 µg/L) at monitoring well 460B, VOCs were detected only at monitoring wells MW-95 and 653. BTEX concentrations at monitoring well MW-95 (130 µg/L benzene, 400 µg/L toluene, 52 µg/L ethylbenzene, and 279 µg/L xylenes) were lower than those measured in October of 1993, with the exception of xylenes which increased. Elevated concentrations of BTEX at monitoring well 653 (330 µg/L benzene, 1,500 µg/L toluene, 180 µg/L ethylbenzene, and 1,260 µg/L xylenes) suggested that a secondary source exists at the RAPCON site.

Groundwater data collected in September 1994 and July 1995 by Parsons ES confirmed the widespread presence of groundwater contamination. Tables 4.3 and 4.4 summarize groundwater BTEX, TMB, TEMB, total fuel carbon, and naphthalene concentrations results from both of these TS sampling events. TMB and TEMB compounds are water-soluble fuel constituents with sorptive properties similar to BTEX, but which can be considered recalcitrant to biological degradation under anaerobic conditions; therefore, these compounds can be used as tracer compounds in the calculation of anaerobic decay rates, as presented in Section 5. Analytical results from the TS investigation are discussed in the following subsections.

4.4.1.1 Dissolved BTEX

The areal distribution of total dissolved BTEX in groundwater for September 1994 and July 1995 are presented on Figures 4.4 and 4.5. Where nested monitoring wells are present, isopleths were drawn on the basis of the maximum detected concentration, which in all instances was detected in the well screened near or across the water table. As indicated by the 1-µg/L isopleth, the BTEX plume varies between approximately 1,050 and 1,150 feet in length, and extends from the vicinity of the fire training pit to Red Fox Creek. The 5,000-µg/L contours in Figure 4.5 clearly show two source areas: one source area is located at the fire training pit, and the other is located at the RAPCON site. The



LEGEND

MW-92 ND	MONITORING WELL INSTALLED PRIOR TO FALL 1993, WITH BTEX CONCENTRATION (µg/L)
460 <1	A-AQUIFER MONITORING WELL INSTALLED FALL 1993, WITH BTEX CONCENTRATION (µg/L)
ESMW-1A 10,100	MONITORING WELL INSTALLED SEPTEMBER 1994, WITH BTEX CONCENTRATION (µg/L)
100	LINE OF EQUAL BTEX CONCENTRATION (µg/L)(DASHED WHERE INFERRED) CONTOUR INTERVAL = VARIABLE
ND	NON DETECT
BTEX	BENZENE, TOLUENE, ETHYLBENZENE XYLENE
*	SAMPLE COLLECTED IN JULY 1994, (EMCON 1994b)
	ESTIMATED GROUNDWATER FLOW DIRECTION

FIGURE 4.4

TOTAL BTEX CONCENTRATION IN SHALLOW GROUNDWATER (SEPTEMBER 1994)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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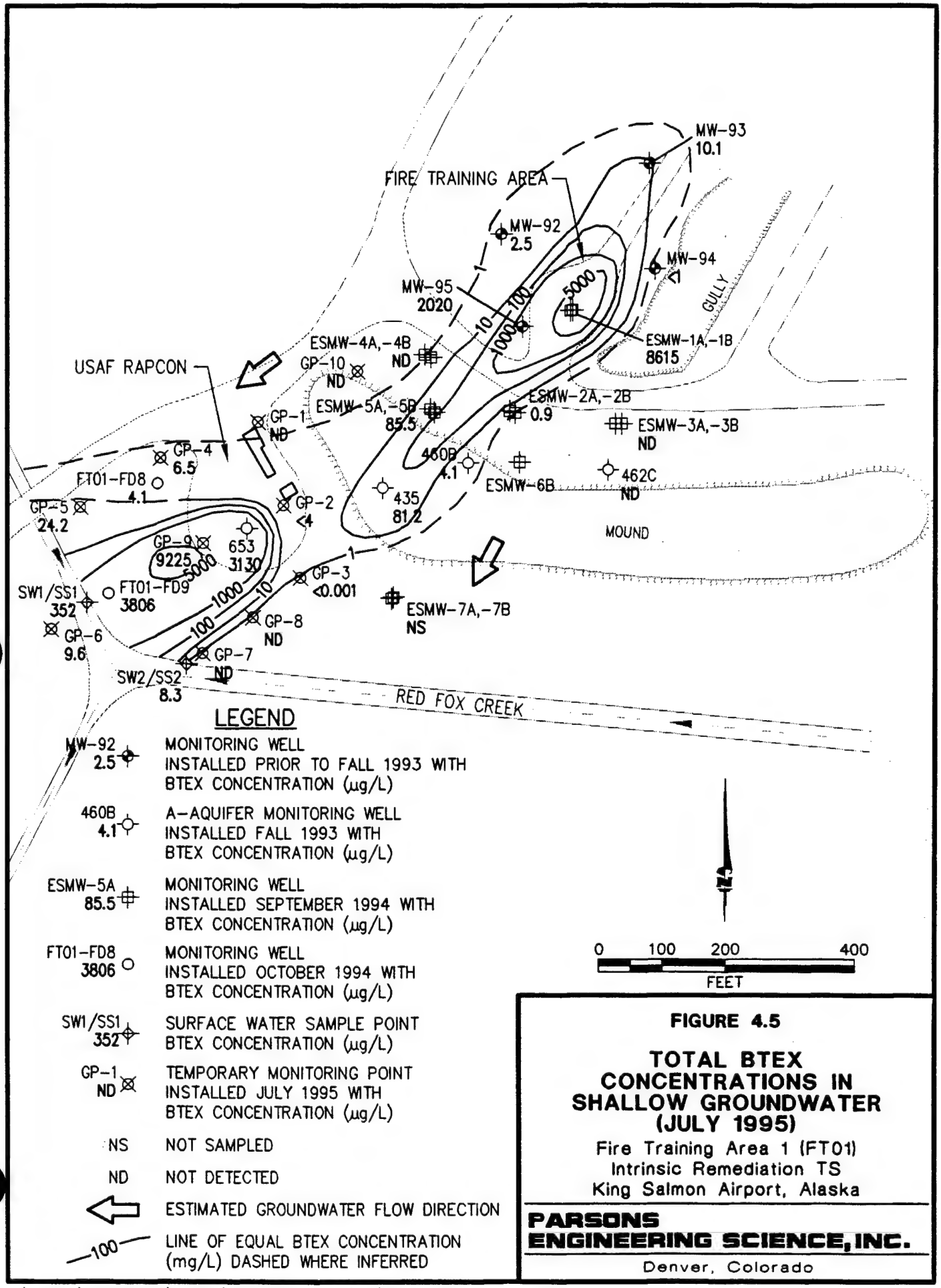

LEGEND

- MW-92 2.5 — MONITORING WELL INSTALLED PRIOR TO FALL 1993 WITH BTEX CONCENTRATION (µg/L)
- 460B 4.1 — A-AQUIFER MONITORING WELL INSTALLED FALL 1993 WITH BTEX CONCENTRATION (µg/L)
- ESMW-5A 85.5 — MONITORING WELL INSTALLED SEPTEMBER 1994 WITH BTEX CONCENTRATION (µg/L)
- FT01-FD8 3806 — MONITORING WELL INSTALLED OCTOBER 1994 WITH BTEX CONCENTRATION (µg/L)
- SW1/SS1 352 — SURFACE WATER SAMPLE POINT BTEX CONCENTRATION (µg/L)
- GP-1 ND — TEMPORARY MONITORING POINT INSTALLED JULY 1995 WITH BTEX CONCENTRATION (µg/L)
- NS — NOT SAMPLED
- ND — NOT DETECTED
- ESTIMATED GROUNDWATER FLOW DIRECTION
- 100 — LINE OF EQUAL BTEX CONCENTRATION (mg/L) DASHED WHERE INFERRED

FIGURE 4.5

TOTAL BTEX CONCENTRATIONS IN SHALLOW GROUNDWATER (JULY 1995)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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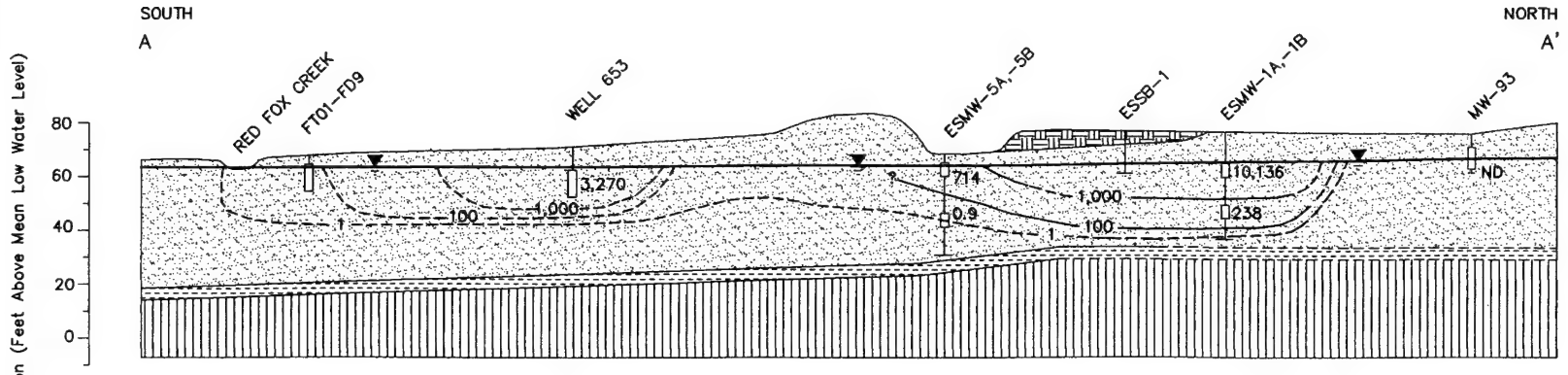
two groundwater plumes appear to merge as contamination migrating from Site FT01 commingles with groundwater contamination at the RAPCON site. Groundwater contamination appears to be discharging to a segment of creek approximately 400 feet long (Figure 4.5). The estimated average areal extent of the total dissolved BTEX plume in 1994 and 1995, as defined by the 1-µg/L contour, was approximately 163,000 square feet (3.7 acres).

The vertical distribution of dissolved BTEX in September 1994 and July 1995 along the main axis of the plume, approximately parallel to the direction of groundwater flow is presented on Figures 4.6 and 4.7, respectively. The maximum depth of the 1-µg/L isopleth from both sampling events below the groundwater surface near the former fire training pit is at least 25 feet, based on measured BTEX concentrations in the deep well at ESMW-2B. The thickness of the contaminant plume in the vicinity of the RAPCON site is unknown, but the plume has penetrated to monitoring well 653, which has a 10-foot screened interval across the groundwater table. It is believed that Red Fox Creek captures the majority of the dissolved BTEX that reaches the creek, as suggested on Figures 4.6 and 4.7. However, a small fraction of the plume appears to underflow Red Fox Creek and migrate further downgradient. BTEX was detected at 9.6 µg/L at monitoring point location GP-6, which is located on the south side of Red Fox Creek, and downgradient from monitoring well FT01-FD9 (Figure 4.5).

Where detected, total BTEX concentrations in September 1994 ranged from <0.1 to 10,100 µg/L (Table 4.3). The maximum concentration of 10,100 µg/L was detected in a groundwater sample collected from ESMW-1A in the center of the former fire training pit. BTEX concentrations detected in July 1995 ranged from <0.1 to 8,620 µg/L (Table 4.3). The maximum BTEX concentration of 8,620 µg/L also was detected in the sample from ESMW-1A. The general shape and extent of the groundwater plumes observed in 1994 and 1995 appear similar; however, the maximum BTEX concentration decreased by approximately 1,500 µg/L from 1994 to 1995. Similarly, BTEX concentrations at the fire training area were observed to decrease between 1994 and 1995 at monitoring wells ESMW-2A, ESMW-3A, ESMW-4A, ESMW-5A, and 435. Over the same period, BTEX concentrations increased at monitoring wells MW-92, MW-93, and MW-95 by concentrations ranging between 2.5 and 1,130 µg/L. Overall, groundwater BTEX concentrations appear to decrease at the fire training site, suggesting that the source area soils have been remediated, and that the BTEX contaminants are being naturally attenuated.

A single groundwater sample from monitoring well 653 at the RAPCON site was collected in July 1994 (EMCON, 1995a). This sample contained 3,270 µg/L of BTEX (Figure 4.4). Data collected as part of this TS in July 1995 show that BTEX concentrations at the RAPCON site ranged from <4 to 9,225 µg/L. The maximum BTEX concentration of 9,225 µg/L was measured at temporary monitoring point GP-9. BTEX concentrations measured at monitoring well 653 in September 1994 and July 1995 decreased by 140 µg/L, which suggests that the contaminant source in this area may not be weathering rapidly. Based on the 10-µg/L isopleth on Figure 4.5, the groundwater BTEX plumes emanating from the fire training site and the RAPCON site do not appear to be commingling at concentrations above 10 µg/L. Figure 4.5 illustrates that the



LEGEND

- Contact
- Approximate Contact
- ESMW-7A,-7B — Well Identification
- Well Borehole Screen
- Bottom of Borehole
- Approximate Location of Water Table
- Brown sandy silt to silty sand FILL. Organic matter present.
- Brown to grey, fine-to medium-grained SAND.
- Brown, silty, sandy GRAVEL. Some subrounded pebbles present.
- Grey, clayey SILT to silty CLAY. Dense and highly plastic. Brown sand lenses present.
- Approximate BTEX Concentration (µg/L)

VERTICAL EXAGGERATION 2.5x

0 100 200

FEET

FIGURE 4.6

VERTICAL DISTRIBUTION OF GROUNDWATER BTEX (SEPTEMBER 1994)

Fire Training Area FT-01
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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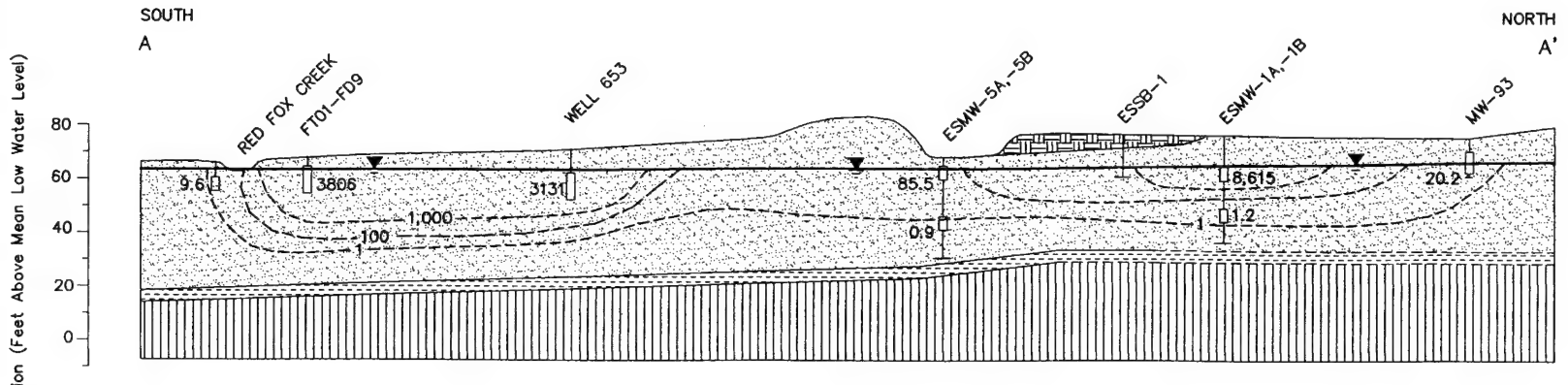

LEGEND

- Contact
- Approximate Contact
- ESMW-7A,-7B — Well Identification
- Well Borehole Screen
- Bottom of Borehole
- Approximate Location of Water Table
- Brown sandy silt to silty sand FILL. Organic matter present.
- Brown to grey, fine-to medium-grained SAND.
- Brown, silty, sandy GRAVEL. Some subrounded pebbles present.
- Grey, clayey SILT to silty CLAY. Dense and highly plastic. Brown sand lenses present.
- Approximate BTEX Concentration (µg/L)

VERTICAL EXAGGERATION 2.5x

0 100 200

FEET

FIGURE 4.7

VERTICAL DISTRIBUTION OF GROUNDWATER BTEX (JULY 1995)

Fire Training Area 1 (FT-01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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majority of groundwater contamination discharging to Red Fox Creek is from the RAPCON site.

The maximum benzene and toluene concentrations of 1,050 µg/L and 6,470 µg/L, respectively, were detected in the groundwater sample collected from ESMW-1A (fire training area) in September 1994. The maximum ethylbenzene and total xylene concentrations of 706 µg/L and 3,319 µg/L, respectively, were detected at GP-9 (RAPCON site) in July 1995. Federal/state groundwater quality standards for the BTEX compounds were exceeded at a number of locations in September 1994 and July 1995, as summarized in Table 4.5.

4.4.1.2 Total Petroleum Hydrocarbons

The distribution of TPH (normalized to JP-4) in groundwater is nearly identical to the distribution of BTEX compounds and the pattern of BTEX attenuation from 1994 to 1995 (Figures 4.8 and 4.9). TPH was only detected at locations where dissolved BTEX compounds were also detected in 1994 and 1995. TPH concentrations ranged from <0.1 to 10,100 µg/L in September 1994 and from <0.1 to 12,800 µg/L in July 1995 (Table 4.3).

4.4.1.3 Chlorinated VOCs

Chlorinated VOCs were detected in groundwater in September 1994 and July 1995. In September 1994, 1,1,1-TCA was the only chlorinated VOC detected in groundwater samples. Detected concentrations ranged from 1.3 to 8.3 µg/L in seven samples (Table 4.3). The maximum 1,1,1-TCA concentration (8.3 µg/L) was observed at monitoring well ESMW-5A, which is several hundred feet downgradient from the fire training pit. A separate field study conducted by EMCON (1994a) detected the presence of 21 µg/L of TCE at monitoring well 653. Non-detectable concentrations of chlorinated VOCs were measured in 14 of the 20 shallow monitoring wells sampled in September 1994. TCA did not exceed the state groundwater quality standard of 200 µg/L at any location where it was detected [Title 18 Alaska Administrative Codes, Part 80 (18AAC80)].

In July 1995, TCE was detected only in groundwater samples collected from the RAPCON site (Table 4.4). No other chlorinated VOCs were detected in groundwater samples collected from the study area. The maximum TCE concentration was detected at temporary monitoring point GP-9 at 636 µg/L. The remaining three sampling locations exhibiting TCE contamination were monitoring wells 653 and FT01-FD9 (24.2 and 137 µg/L, respectively) and temporary monitoring point GP-6 (14.1 µg/L). The source of TCE contamination coincides with observed BTEX contamination at the RAPCON site (Section 4.5.1.1). TCE was observed to increase slightly in concentration at monitoring well 653 between September 1994 and July 1995, suggesting that TCE contamination in the vadose zone had not attenuated. The location of monitoring well FT01-FD9 suggests that approximately 140 µg/L of TCE may be present in groundwater discharging to Red Fox Creek. TCE exceeded the state groundwater quality standard of 5 µg/L at all four locations where it was detected.

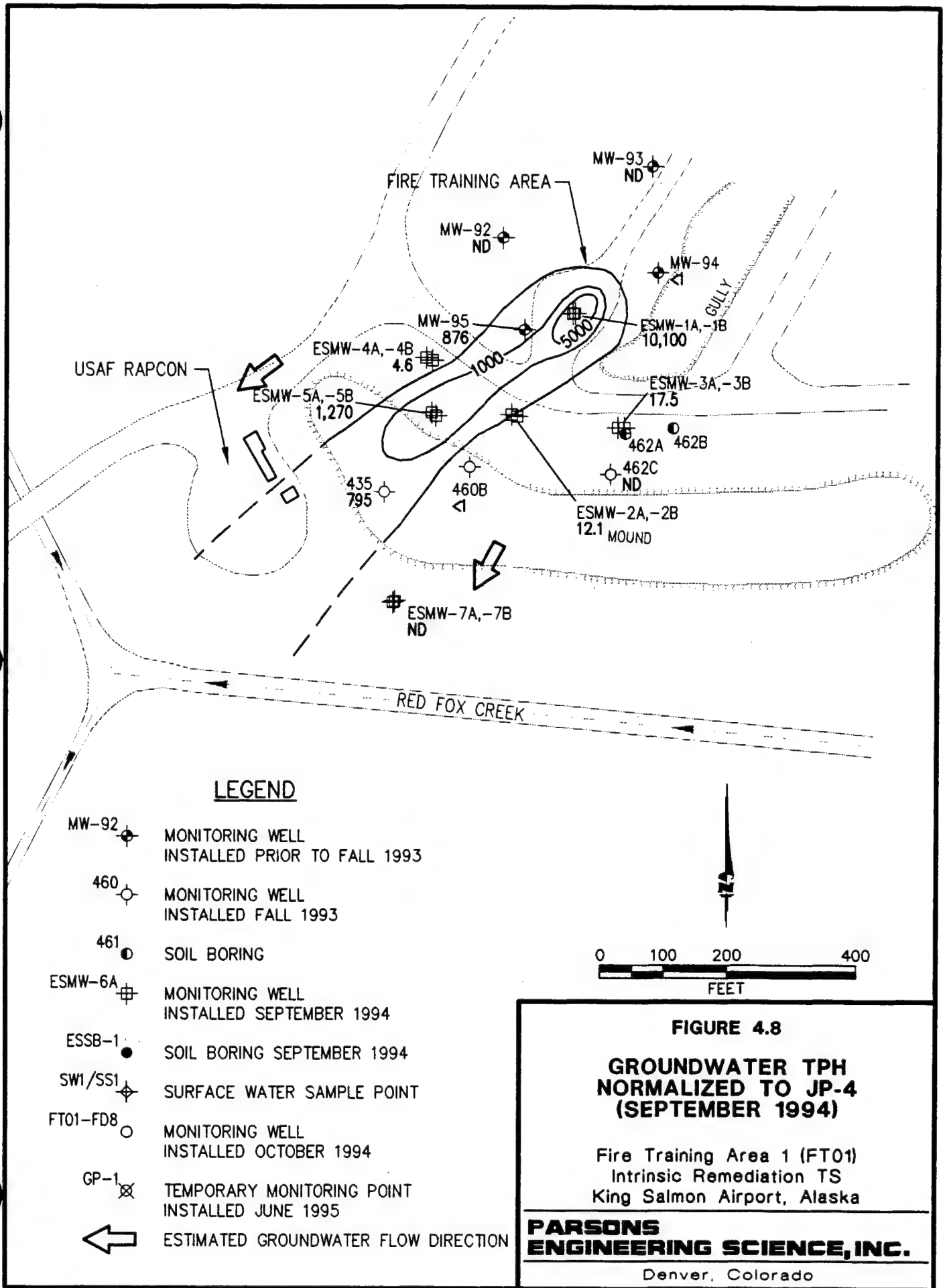

FIGURE 4.8

GROUNDWATER TPH NORMALIZED TO JP-4 (SEPTEMBER 1994)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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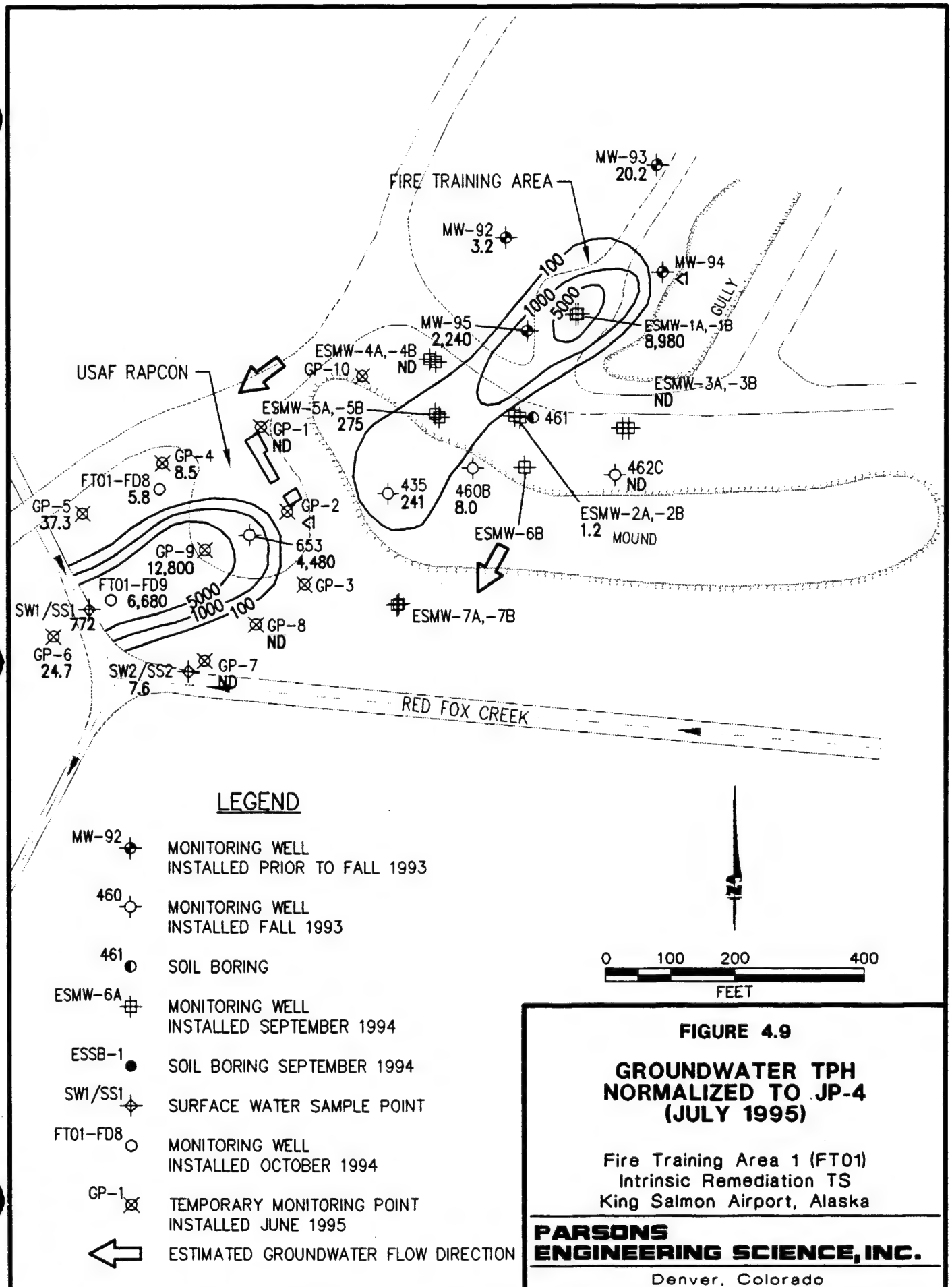

FIGURE 4.9

GROUNDWATER TPH NORMALIZED TO JP-4 (JULY 1995)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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TABLE 4.5
FEDERAL AND/OR STATE GROUNDWATER QUALITY STANDARD EXCEEDANCES
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Compound	Federal or State Groundwater Quality Standard (µg/L)	Number of Locations Exceeding Groundwater Quality Standard September 1994	Number of Locations Exceeding Groundwater Quality Standard July 1995
Benzene	5 [a/]	7 of 21	7 of 29
Toluene	1,000 [a/]	2 of 21	4 of 29
Ethylbenzene	700 [a/]	0 of 21	1 of 29
Xylenes	10,000 [a/]	0 of 21	0 of 29
Total Aromatic Hydrocarbons (BTEX)	10 [a/]	8 of 21	9 of 29

[a/] Federal maximum contaminant level (USEPA, 1995).

[b/] State of Alaska Water Quality Standard [18 Alaska Administrative Code (AAC) 70].

4.4.2 Inorganic Chemistry and Geochemical Indicators of BTEX and TCE Biodegradation

Microorganisms obtain energy for cell production and maintenance by facilitating thermodynamically advantageous redox reactions involving the transfer of electrons from electron donors to available electron acceptors. This results in the oxidation of the electron donor and the reduction of the electron acceptor. The primary electron donors at the site are fuel hydrocarbon compounds. Other potential electron donors are natural organic carbon; however, background TOC concentrations at the site were low (Section 3.2). Fuel hydrocarbons are completely degraded or detoxified if they are utilized as the primary electron donor for microbial metabolism (Bouwer, 1992). Electron acceptors are elements or compounds that occur in relatively oxidized states, and may include oxygen, nitrate, ferric iron, sulfate, manganese, and carbon dioxide. TCE also is a potential electron acceptor under nitrate- and sulfate-reducing conditions, with the most rapid biodegradation rates occurring under methanogenic conditions (Bouwer, 1994).

The driving force of BTEX degradation is electron transfer, which is quantified by the Gibbs free energy of the reaction ($\Delta G°_r$) (Stumm and Morgan, 1981; Bouwer, 1994; Godsey, 1994). The value of $\Delta G°_r$ represents the quantity of free energy consumed or yielded to the system during the reaction. Table 4.6 lists stoichiometry of the redox equations involving BTEX and the resulting $\Delta G°_r$. Although thermodynamically favorable, most of the reactions involved in BTEX oxidation cannot proceed abiotically because of the lack of activation energy. Microorganisms are capable of providing the necessary activation energy; however, they will facilitate only those redox reactions that have a net yield of energy (i.e. $\Delta G°_r < 0$). Microorganisms preferentially utilize electron acceptors while metabolizing fuel hydrocarbons (Bouwer, 1992). DO is utilized first as the prime electron acceptor. After the DO is consumed, anaerobic microorganisms use

TABLE 4.6
COUPLED OXIDATION REACTIONS FOR BTEX COMPOUNDS
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Coupled Benzene Oxidation Reactions	$\Delta G°_r$ (kcal/mole Benzene)	$\Delta G°_r$ (kJ/mole Benzene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$7.5O_2 + C_6H_6 \Rightarrow 6CO_{2,g} + 3H_2O$ *Benzene oxidation /aerobic respiration*	-765.34	-3202	3.07:1
$6NO_3^- + 6H^+ + C_6H_6 \Rightarrow 6CO_{2,g} + 6H_2O + 3N_{2,g}$ *Benzene oxidation / denitrification*	-775.75	-3245	4.77:1
$3.75\,NO_3^- + C_6H_6 + 7.5\,H^+ + 0.75\,H_2O \Rightarrow 6\,CO_2 + 3.75\,NH_4^+$ *Benzene oxidation / nitrate reduction*	-524.1	-2193	2.98:1
$60H^+ + 30Fe(OH)_{3,a} + C_6H_6 \Rightarrow 6CO_2 + 30Fe^{2+} + 78H_2O$ *Benzene oxidation / iron reduction*	-560.10	-2343	21.5:1[a/]
$7.5H^+ + 3.75SO_4^{2-} + C_6H_6 \Rightarrow 6CO_{2,g} + 3.75H_2S° + 3H_2O$ *Benzene oxidation / sulfate reduction*	-122.93	-514.3	4.61:1
$4.5H_2O + C_6H_6 \Rightarrow 2.25CO_{2,g} + 3.75CH_4$ *Benzene oxidation / methanogenesis*	-32.40	-135.6	0.77:1 [b/]

Coupled Toluene Oxidation Reactions	$\Delta G°_r$ (kcal/mole Toluene)	$\Delta G°_r$ (kJ/mole Toluene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$9O_2 + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 4H_2O$ *Toluene oxidation /aerobic respiration*	-913.76	-3823	3.13:1
$7.2NO_3^- + 7.2H^+ + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 7.6H_2O + 3.6N_{2,g}$ *Toluene oxidation / denitrification*	-926.31	-3875	4.85:1
$72H^+ + 36Fe(OH)_{3,a} + C_6H_5CH_3 \Rightarrow 7CO_2 + 36Fe^{2+} + 94H_2O$ *Toluene oxidation / iron reduction*	-667.21	-2792	21.86:1[a/]
$9H^+ + 4.5SO_4^{2-} + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 4.5H_2S° + 4H_2O$ *Toluene oxidation / sulfate reduction*	-142.86	-597.7	4.7:1
$5H_2O + C_6H_5CH_3 \Rightarrow 2.5CO_{2,g} + 4.5CH_4$ *Toluene oxidation / methanogenesis*	-34.08	-142.6	0.78:1 [b/]

TABLE 4.6 (Concluded)
COUPLED OXIDATION REACTIONS FOR BTEX COMPOUNDS
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Coupled Ethylbenzene Oxidation reactions	$\Delta G°_r$ (kcal/mole Ethyl-benzene)	$\Delta G°_r$ (kJ/mole Ethyl-benzene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$10.5O_2 + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 5H_2O$ *Ethylbenzene oxidation /aerobic respiration*	-1066.13	-4461	3.17:1
$8.4NO_3^- + 8.4H^+ + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 9.2H_2O + 4.2N_{2,g}$ *Ethylbenzene oxidation / denitrification*	-1080.76	-4522	4.92:1
$84H^+ + 42Fe(OH)_{3,a} + C_6H_5C_2H_5 \Rightarrow 8CO_2 + 42Fe^{2+} + 110H_2O$ *Ethylbenzene oxidation / iron reduction*	-778.48	-3257	22:1[a/]
$10.5H^+ + 5.25SO_4^{2-} + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 5.25H_2S^o + 5H_2O$ *Eth* *ylbenzene oxidation / sulfate reduction*	-166.75	-697.7	4.75:1
$5.5H_2O + C_6H_5C_2H_5 \Rightarrow 2.75CO_{2,g} + 5.25CH_4$ *Ethylbenzene oxidation / methanogenesis*	-39.83	-166.7	0.79:1 [b/]

Coupled m-Xylene Oxidation Reactions	$\Delta G°_r$ (kcal/mole *m*-xylene)	$\Delta G°_r$ (kJ/mole *m*-xylene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$10.5O_2 + C_6H_4(CH_3)_2 \Rightarrow 8CO_{2,g} + 5H_2O$ *m-Xylene oxidation /aerobic respiration*	-1063.25	-4448	3.17:1
$8.4NO_3^- + 8.4H^+ + C_6H_4(CH_3)_2 \Rightarrow 8CO_{2,g} + 9.2H_2O + 4.2N_{2,g}$ *m-Xylene oxidation / denitrification*	-1077.81	-4509	4.92:1
$84H^+ + 42Fe(OH)_{3,a} + C_6H_4(CH_3)_2 \Rightarrow 8CO_2 + 42Fe^{2+} + 110H_2O$ *m-Xylene oxidation / iron reduction*	-775.61	-3245	22:1[a/]
$10.5H^+ + 5.25SO_4^{2-} + C_6H_4(CH_3)_2 \Rightarrow 8CO_{2,g} + 5.25H_2S^o + 5H_2O$ *m-Xylene oxidation / sulfate reduction*	-163.87	-685.6	4.75:1
$5.5H_2O + C_6H_4(CH_3)_2 \Rightarrow 2.75CO_{2,g} + 5.25CH_4$ *m-Xylene oxidation / methanogenesis*	-36.95	-154.6	0.79:1 [b/]

[a/] Mass of ferrous iron produced during microbial respiration.

[b/] Mass of methane produced during microbial respiration.

electron acceptors in the following order of preference: nitrate, manganese, ferric iron hydroxide, sulfate, and finally carbon dioxide.

Depending on the types and concentrations of electron acceptors present, pH conditions, and redox potentials, anaerobic biodegradation of BTEX can occur by denitrification, manganese reduction, ferric iron reduction, sulfate reduction, or methanogenesis. Other, less common anaerobic degradation mechanisms such as nitrate reduction may dominate if the physical and chemical conditions in the subsurface favor use of these electron acceptors. Anaerobic destruction of the BTEX compounds is associated with the accumulation of fatty acids, production of methane, solubilization of iron and manganese, and reduction of nitrate and sulfate (Cozzarelli *et al.*, 1990; Wilson *et al.*, 1990). Environmental conditions and microbial competition ultimately determine which processes will dominate. Vroblesky and Chapelle (1994) show that the dominant terminal electron accepting process can vary both temporally and spatially in an aquifer with fuel hydrocarbon contamination.

As with BTEX, the driving force behind redox reactions resulting in chlorinated VOC degradation is electron transfer. Although thermodynamically favorable, most of the reactions involved in chlorinated VOC reduction and oxidation, including TCE, cannot proceed abiotically because of the lack of activation energy. Similar to BTEX biodegradation, it is possible for microorganisms to facilitate redox reactions involving TCE; however, microorganisms are generally believed to be incapable of growth using TCE as an electron donor (Murray and Richardson, 1993). Therefore, the reactions typically are a result of reductive dehalogenation or cometabolism. Geochemical patterns involving nitrate, manganese, ferric iron hydroxide, sulfate, and carbon dioxide can suggest an expected process and a general rate (i.e., rapid or slow) for TCE biodegradation.

The most common, and potentially rapid, process for TCE biodegradation is reductive dehalogenation. During reductive dehalogenation, TCE is used as an electron acceptor, not as a source of carbon, and a halogen atom is removed and replaced with a hydrogen atom. Therefore, dissolved BTEX contamination at the RAPCON site may potentially be used as electron donor for the reductive dehalogenation of TCE. The general sequence of the reductive dechlorination of TCE is from TCE to DCE to vinyl chloride (VC) to ethene. None of the sequential daughter products produced from the reductive dechlorination of TCE were observed at the study area (Section 4.5.1.3), suggesting that the reductive dehalogenation of TCE is not an important process at the study area.

TCE degradation can also occur by cometabolism, the fortuitous degradation of TCE as a result of the presence of enzymes or cofactors that were produced by microorganisms for other purposes. TCE and other chlorinated VOCs have been documented to be cometabolized under aerobic conditions (Murray and Richardson, 1993; Vogel, 1994, McCarty and Semprini, 1994). Except in isolated cases, the rate of TCE degradation through cometabolism is believed to be relatively slow. The aerobic cometabolism of TCE may be characterized by a loss of TCE mass, the presence of intermediate degradation products (e.g., chlorinated oxides, aldehydes, ethanols, and epoxides) and the presence of chloroform. Elevated BTEX concentrations commingled with TCE at the RAPCON site suggest that cometabolism may be a potential TCE degradation

mechanism, although no oxygenated intermediate degradation products were measured to confirm this conclusion.

Site groundwater data for DO suggest that intrinsic remediation of hydrocarbons in the shallow aquifer is occurring by aerobic biodegradation. In addition, data for soluble nitrate and ferrous iron (Fe^{2+}) suggest that anaerobic degradation of BTEX via denitrification and ferric iron reduction is occurring. It is also possible that some TCE biodegrades through cometabolism. Geochemical parameters for site groundwater are discussed in the following sections.

4.4.2.1 Dissolved Oxygen

DO concentrations were measured at monitoring wells and points during the September 1994 and July 1995 sampling events. Concentrations ranged from 0.4 to 9.0 mg/L in September 1994, and from 0.3 to 10.4 mg/L in July 1995. Table 4.7 summarizes measured DO concentrations. Figures 4.10 and 4.11 illustrate DO concentrations at the site. As a result of high overall DO in groundwater at background monitoring points and/or at the periphery of the groundwater contaminant plume, DO is considered to be an important electron acceptor at this site. Because DO is recharged in the shallow groundwater through rainwater infiltration, small, seasonal contributions to the degradation of fuel constituents through aerobic respiration can be expected, in addition to the normal recharge of DO from upgradient sources of groundwater.

The stoichiometry of BTEX mineralization to carbon dioxide and water caused by aerobic microbial biodegradation is presented in Table 4.6. The average mass ratio of oxygen to total BTEX is approximately 3.14 to 1. This translates to the mineralization of approximately 0.32 mg of BTEX for every 1.0 mg of DO consumed. During both the 1994 and 1995 sampling events, an average background DO for Site FT01 was computed from concentrations in monitoring wells MW-93, MW-94, and ESMW-4A. Each of these wells is located upgradient from or peripheral to groundwater contamination. Likewise, during both the 1994 and 1995 sampling events, an average DO concentration was computed from results from ESMW-1A and MW-95 in the vicinity of the former fire training pit. The distribution of DO between 1994 and 1995 differed as noted by higher DO concentrations in background and peripheral wells in 1994 (Figures 4.10 and 4.11). Using an average site background DO concentration in September 1994 of approximately 6.8 mg/L and an average DO concentration in the source area of approximately 0.8 mg/L, the shallow groundwater at Site FT01 had the capacity to assimilate 1.91 mg/L (1,910 µg/L) of total BTEX through aerobic biodegradation in September 1994. Similarly, using an average site background DO concentration in July 1995 of approximately 2.8 mg/L and an average DO concentration in the source area of approximately 0.9 mg/L, the shallow groundwater at Site FT01 had the capacity to assimilate 0.61 mg/L (610 µg/L) of total BTEX through aerobic biodegradation in July 1995.

Available DO data for July 1995 suggests that groundwater contamination at the RAPCON site was significant on the basis of decreases in groundwater DO concentrations. Assuming an average background DO concentration in July 1995 for the RAPCON site (taken from temporary monitoring points GP-2 through GP-4) of approximately 8.7 µg/L, and an average DO concentration in the estimated source area

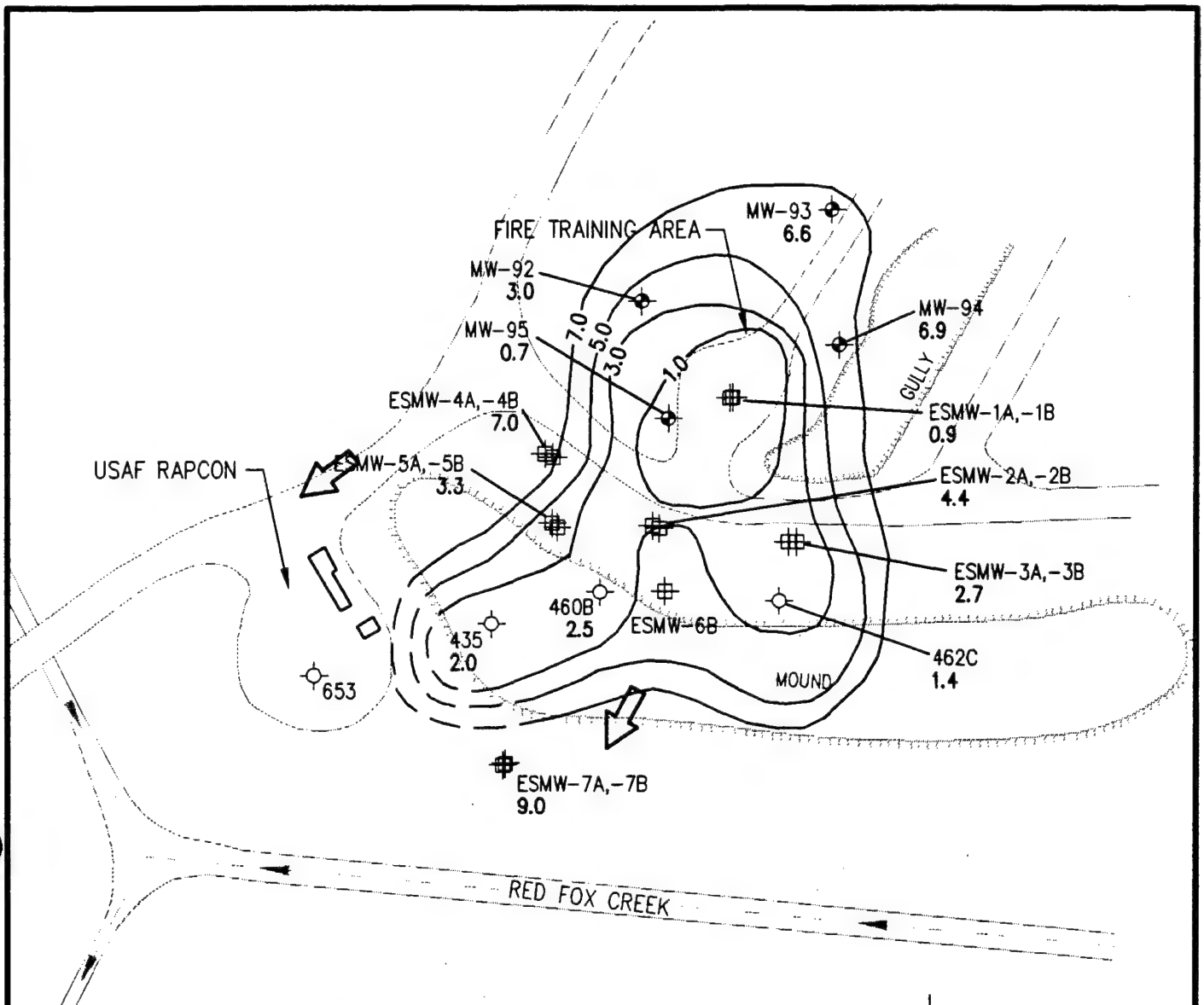
TABLE 4.7
GEOCHEMICAL DATA FOR GROUNDWATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Redox (mV)	Chloride (mg/L)	Sulfate (mg/L)	Ferrous Iron (mg/L)	Soluble Manganese (mg/L)	Free CO_2 (mg/L)	NO_2^- + NO_3^- Nitrogen (mg/L)	Conductivity (µs/cm)	Alkalinity $CaCO_3$ (mg/L)	Methane (mg/L)	TOC (mg/L)
ESMW-1A	9/94	6.7	0.9	6.50	63	2.93	3.43	2.5	0.9	140	0.09	300	132.0	NA[a/]	27.30
ESMW-1A	7/95	4.9	1.4	6.81	35	2.07	1.39	3.0	NA	40	<0.05	161	81.6	<0.001	1.40
ESMW-1B	9/94	5.4	2.1	6.80	202	3.43	<0.5	<0.05	<0.1	10	0.38	104	21.0	NA	1.60
ESMW-1B	7/95	4.6	2.0	6.85	150	3.47	3.71	<0.1	NA	25	0.25	134	68.0	<0.001	2.20
ESMW-2A	9/94	8.2	4.4	6.50	288	2.98	6.38	<0.05	NA	NA	2.69	195	67.0	0.002	6.50
ESMW-2A	7/95	4.6	5.1	6.72	240	2.42	4.80	<0.1	NA	35	1.38	117	54.4	<0.001	5.10
ESMW-2B	9/94	7.8	0.4	6.40	265	3.36	3.44	<0.05	NA	NA	0.11	141	58.0	0.063	2.60
ESMW-2B	7/95	5.5	0.4	6.50	230	3.04	3.13	<0.1	NA	50	0.38	113	54.4	<0.001	3.10
ESMW-3A	9/94	6.7	2.7	6.60	288	2.80	2.85	<0.05	0.1	NA	0.05	97	38.0	0.041	6.90
ESMW-3A	7/95	7.1	1.4	6.61	235	3.70	0.97	<0.1	NA	30	<0.05	100	47.6	0.126	2.40
ESMW-3B	9/94	5.9	1.0	6.50	284	3.71	3.56	<0.05	<0.1	NA	0.55	106	44.0	<0.001	1.30
ESMW-4A	9/94	6.8	7.0	6.20	280	3.57	4.00	<0.05	<0.1	40	0.60	120	47.0	0.002	8.20
ESMW-4A	7/95	4.8	5.2	6.52	250	3.99	3.16	<0.1	NA	90	2.52	157	68.0	0.001	6.20
ESMW-4B	9/94	6.9	7.5	7.00	271	3.88	2.61	<0.05	<0.1	12	0.40	81	9.0	<0.001	2.10
ESMW-5A	9/94	7.4	3.3	6.80	254	2.96	3.21	<0.05	0.2	48	0.37	239	84.0	<0.001	5.70
ESMW-5A	7/95	8.0	1.4	6.73	230	3.59	2.33	<0.1	NA	45	<0.05	162	81.6	<0.001	3.10
ESMW-5B	9/94	5.6	1.4	7.70	242	3.51	2.79	<0.05	<0.1	8	0.11	134	57.0	0.002	1.40
ESMW-5B	7/95	7.0	0.3	7.38	200	3.43	2.20	<0.1	NA	15	<0.05	146	74.8	0.001	1.20
ESMW-6B	9/94	7.3	4.0	6.40	297	3.50	3.53	<0.05	<0.1	24	0.23	109	40.0	<0.001	3.40
ESMW-6B	7/95	7.6	0.4	6.61	250	2.44	1.52	<0.1	NA	30	<0.05	87	54.4	0.074	2.00
ESMW-7A	9/94	5.9	9.0	6.30	266	4.51	5.26	<0.05	0.2	36	2.82	188	43.0	<0.001	2.70
ESMW-7B	9/94	5.0	0.7	6.50	262	3.35	1.30	<0.05	0.1	40	<0.05	133	55.0	0.186	1.90
FT01-FD9	7/95	4.5	0.5	6.92	-35	3.38	<0.5	5.0	NA	70	<0.05	323	177.0	<0.001	10.20
FT01-FD8	7/95	5.5	6.0	6.42	200	6.02	2.91	<0.1	NA	55	2.21	150	54.4	<0.001	2.20
MW-92	9/94	5.0	3.0	6.10	219	3.49	3.13	<0.05	<0.1	44	0.92	134	45.0	0.001	6.50
MW-92	7/95	4.3	2.6	6.58	220	2.81	3.61	<0.1	NA	35	1.07	104	47.6	<0.001	3.60
MW-93	9/94	6.1	6.6	6.10	220	2.71	2.97	<0.05	<0.1	40	0.34	80	24.0	0.004	4.30
MW-93	7/95	4.6	2.5	6.50	220	3.39	2.77	<0.1	NA	30	0.13	70	34.0	0.123	1.60
MW-94	9/94	9.0	6.9	6.40	207	2.10	0.85	<0.05	<0.1	17	<0.05	86	36.0	0.087	1.40
MW-94	7/95	5.7	0.8	6.92	125	2.51	1.61	<0.1	NA	20	<0.05	74	40.8	0.390	1.50

TABLE 4.7 (Concluded)
GEOCHEMICAL DATA FOR GROUND WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Redox (mV)	Chloride (mg/L)	Sulfate (mg/L)	Ferrous Iron (mg/L)	Soluble Manganese (mg/L)	Free CO_2 (mg/L)	NO_2^-+ NO_3^- Nitrogen (mg/L)	Conductivity (µs/cm)	Alkalinity $CaCO_3$ (mg/L)	Methane (mg/L)	TOC (mg/L)
MW-95	9/94	5.9	0.7	6.60	55	3.07	1.96	1.2	0.4	32	0.06	141	58.0	0.060	4.50
MW-95	7/95	6.1	0.4	6.72	15	3.30	1.60	3.0	NA	35	<0.05	116	74.8	<0.001	5.00
435	9/94	5.0	2.0	7.10	214	2.79	2.78	<0.05	0.5	10	<0.05	276	116.0	0.135	5.50
435	7/95	5.4	1.8	7.19	205	2.53	1.01	<0.1	NA	20	0.11	141	74.8	0.001	4.30
460B	9/94	7.2	2.5	6.50	240	2.90	6.91	<0.05	0.4	48	0.55	233	89.0	<0.001	5.80
460B	7/95	5.0	3.6	6.62	260	2.78	5.85	<0.1	NA	30	0.79	161	81.6	<0.001	5.30
462C	9/94	6.8	1.4	6.30	282	2.36	1.80	<0.05	<0.1	90	0.14	97	41.0	0.072	4.80
462C	7/95	10.0	1.0	6.91	145	2.65	0.94	<0.1	NA	35	0.13	78	40.8	0.045	2.60
653	7/95	5.4	2.9	6.95	65	3.17	2.90	5.0	NA	55	0.34	181	47.6	<0.001	4.80
GP-1	7/95	5.3	2.2	6.36	225	4.17	1.89	<0.1	NA	75	2.41	172	81.6	<0.001	1.80
GP-2	7/95	4.6	9.9	6.61	95	2.15	<0.5	<0.1	NA	25	1.41	75	40.8	<0.001	1.50
GP-3	7/95	4.4	5.8	6.83	165	3.19	1.67	<0.1	NA	25	0.80	120	54.4	<0.001	1.70
GP-4	7/95	6.1	10.4	6.72	200	3.77	1.29	<0.1	NA	30	1.05	107	40.8	<0.001	1.80
GP-5	7/95	NA	NA	6.45	155	3.81	3.01	<0.1	NA	30	0.89	89	40.8	<0.001	3.20
GP-6	7/95	4.9	0.8	7.02	90	3.53	3.03	<0.1	NA	15	2.31	161	61.2	0.025	1.90
GP-7	7/95	2.5	0.7	6.37	145	4.27	4.00	2.5	NA	70	2.09	184	74.8	0.032	3.40
GP-8	7/95	5.5	0.0	6.46	100	2.31	1.77	<0.1	NA	30	2.02	93	27.2	<0.001	1.50
GP-9	7/95	5.9	0.5	6.78	-65	3.27	3.49	15.0	NA	105	<0.05	415	23.1	<0.001	12.30
GP-10	7/95	5.1	0.4	6.33	240	3.27	3.51	<0.1	NA	90	1.66	204	102.0	<0.001	6.80

NA = Data not Available



LEGEND

MW-92 3.0 — MONITORING WELL INSTALLED PRIOR TO FALL 1993, WITH DISSOLVED OXYGEN CONCENTRATION (mg/L)

460 2.5 — MONITORING WELL INSTALLED FALL 1993, WITH DISSOLVED OXYGEN CONCENTRATION (mg/L)

ESMW-1A 3.3 — MONITORING WELL INSTALLED SEPTEMBER 1994, WITH DISSOLVED OXYGEN CONCENTRATION (mg/L)

9.0 — LINE OF EQUAL DISSOLVED OXYGEN CONCENTRATION (mg/L) (DASHED WHERE INFERRED) CONTOUR INTERVAL = 2.0 mg/L

ESTIMATED GROUNDWATER FLOW DIRECTION

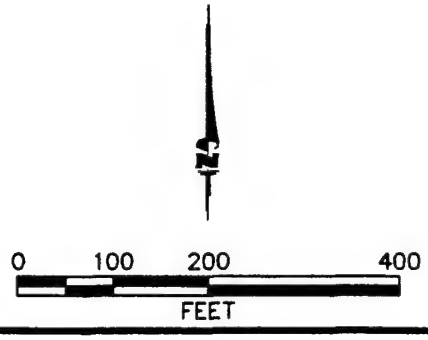


FIGURE 4.10

DISSOLVED OXYGEN ISOPLETH MAP FOR SHALLOW GROUNDWATER (SEPTEMBER 1994)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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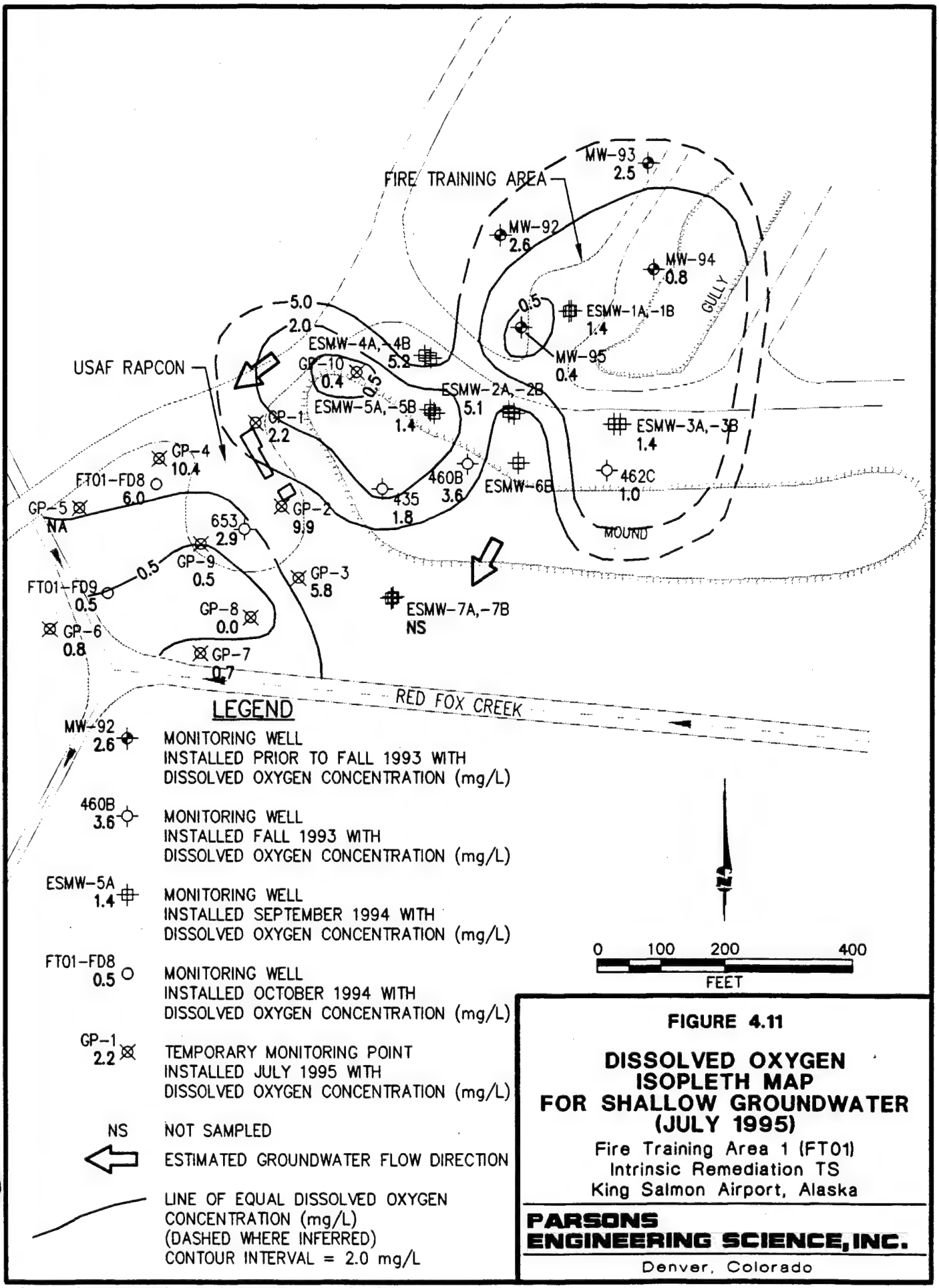

FIGURE 4.11

DISSOLVED OXYGEN ISOPLETH MAP FOR SHALLOW GROUNDWATER (JULY 1995)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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(taken from temporary monitoring points GP-8 and GP-9) of 0.25 mg/L, the shallow groundwater in the vicinity of the RAPCON site had the capacity to assimilate 2.69 mg/L of total BTEX through aerobic biodegradation. This estimate of assimilative capacity for the RAPCON area is high relative to that calculated for the fire training area in July 1995, and suggests that contribution of infiltration recharge near the RAPCON site may be greater than at Site FT01 because of the thinner vadose zone in this area (Figure 3.3).

As a microbial population in the groundwater grows in response to the introduction of fuel hydrocarbons into the groundwater, new cell mass is generated. When cell mass production is accounted for, the mineralization of benzene to carbon dioxide and water is given by:

$$C_6H_6 + 2.5O_2 + HCO_3 + NH_4 \rightarrow C_5H_7O_2N + 2CO_2 + 2H_2O$$

This equation indicates that 5.0 fewer moles of DO are required to mineralize 1 mole of benzene when cell mass production is taken into account. On a mass basis, the ratio of DO to benzene is given by:

Benzene $6(12) + 1(6) = 78$ gm

Oxygen $2.5(32) = 80$ gm

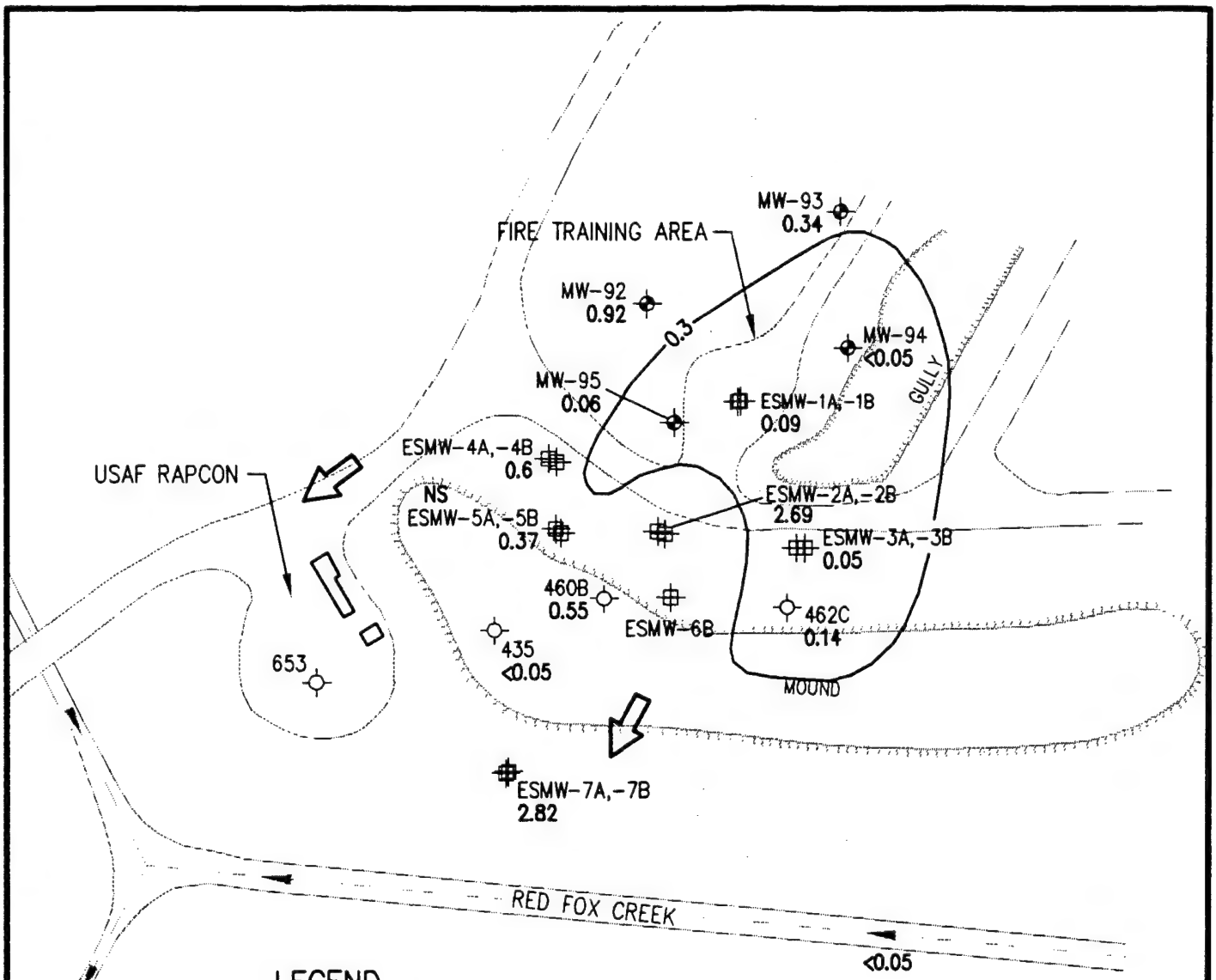
Mass Ratio of Oxygen to Benzene = 80/78 = 1.03:1

On the basis of these stoichiometric relationships, 1.03 mg of oxygen are required to mineralize 1 mg of benzene, if cell mass production is taken into account. Similar calculations can be made for toluene, ethylbenzene, and the xylenes. On the basis of these calculations, approximately 0.97 mg of BTEX is mineralized to carbon dioxide and water for every 1.0 mg of DO consumed.

Although this process results in more efficient utilization of electron acceptors, it is only applicable as the net cell mass of the microbial population continues to grow. Because groundwater contamination has been present at Site FT01 (also suspected at the RAPCON site) for several years, it is expected that biomass production is only a small percentage of the overall energy use because the assimilation of BTEX has reached steady-state. Therefore, the cell mass reaction equations would no longer apply, and the assimilative capacity estimate based on no biomass production is considered more accurate. The steady-state production of cell mass as applied to anaerobic mechanisms is also likely, and the following calculations of anaerobic assimilative capacity estimates assume steady-state conditions within the dissolved contaminant plumes (i.e., biomass production represents a very small fraction of energy use).

4.4.2.2 Nitrate/Nitrite

Concentrations of nitrate/nitrite [as nitrogen (N)] were measured in groundwater samples collected in September 1994 and July 1995. Table 4.7 summarizes measured nitrate/nitrite (as N) concentrations. Figures 4.12 and 4.13 are isopleth maps showing the areal extent of nitrate in groundwater. Nitrate/nitrite (as N) concentrations ranged from <0.05 to 2.69 mg/L in September 1994 and from <0.05 to 2.52 mg/L in July 1995. As



LEGEND

MW-92 0.92 — MONITORING WELL INSTALLED PRIOR TO FALL 1993 WITH NITRATE + NITRITE, (N) CONCENTRATIONS (mg/L)

460B 0.55 — MONITORING WELL INSTALLED FALL 1993 WITH NITRATE + NITRITE, (N) CONCENTRATIONS (mg/L)

ESMW-5A 0.37 — MONITORING WELL INSTALLED SEPTEMBER 1994 WITH NITRATE + NITRITE, (N) CONCENTRATIONS (mg/L)

FT01-FD8 NS — MONITORING WELL INSTALLED OCTOBER 1994 WITH NITRATE + NITRITE, (N) CONCENTRATIONS (mg/L)

NS — NOT SAMPLED

ESTIMATED GROUNDWATER FLOW DIRECTION

0.3 — LINE OF EQUAL NITRATE + NITRITE, (N) CONCENTRATION (mg/L) (DASHED WHERE INFERRED)

N

0 100 200 400
FEET

FIGURE 4.12

NITRATE + NITRITE ISOPLETHS FOR SHALLOW GROUNDWATER (1994)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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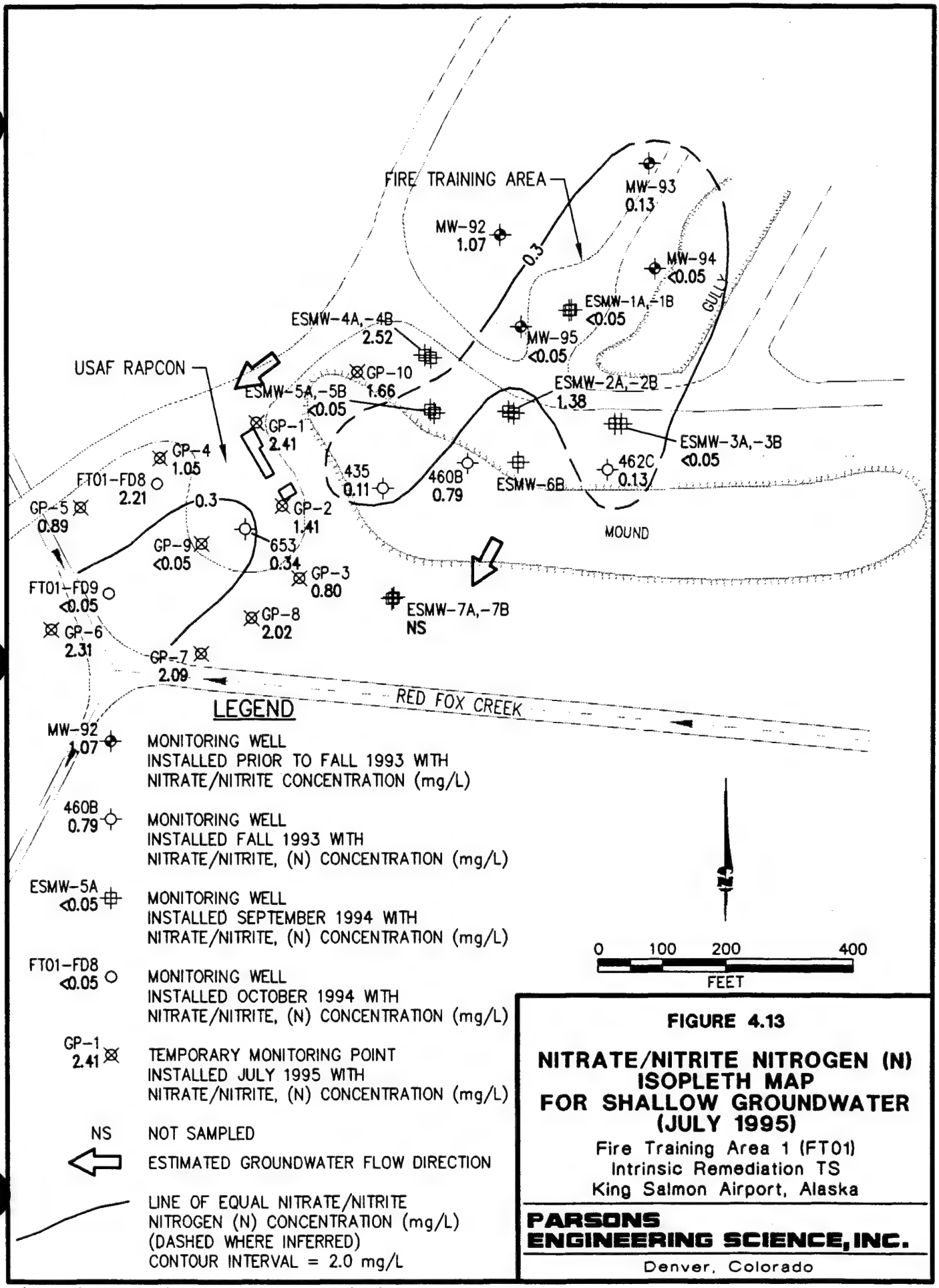

FIGURE 4.13

NITRATE/NITRITE NITROGEN (N) ISOPLETH MAP FOR SHALLOW GROUNDWATER (JULY 1995)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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shown on Figure 4.12 and 4.13, nitrate concentrations were generally reduced in areas coinciding with high concentrations of dissolved BTEX. This relationship provides evidence that BTEX biodegradation is occurring through the microbially mediated process of denitrification

In the absence of microbial cell production, the stoichiometry of BTEX mineralization to carbon dioxide, water, and nitrogen caused by denitrification is presented in Table 4.6. The average mass ratio of nitrate to total BTEX is approximately 4.9 to 1. This translates to the mineralization of approximately 0.20 mg of BTEX for every 1.0 mg of nitrate consumed. This ratio of nitrate consumption assumes that nitrate nitrogen is reported as nitrate ion (NO_3) instead of elemental nitrogen (N). The nitrate nitrogen concentrations shown in Table 4.7 are reported as N, and must be multiplied by 4.42 to be converted into nitrate nitrogen concentrations as NO_3.

During both the 1994 and 1995 sampling events, an average background nitrate concentrations for Site FT01 was computed from concentrations in monitoring wells MW-92, MW-93, and ESMW-4A. Each of these wells is located upgradient from or peripheral to groundwater contamination. Likewise, during both the 1994 and 1995 sampling events, an average nitrate concentration was computed from results from two wells in the vicinity of the former fire training pit, ESMW-1A and MW-95. Using an average background concentration of 2.74 mg/L nitrate (as NO_3) [nitrate nitrogen (as N) in Table 4.7 was converted to nitrate nitrogen (as NO_3) by multiplying by 4.42] and an average nitrate concentration in the source area of 0.33 mg/L nitrate (as NO_3), the shallow groundwater conditions for the fire training area had the capacity to assimilate 0.49 mg/L (490 µg/L) of total BTEX through denitrification in September 1994. Similarly, using an average background concentration of 5.48 mg/L nitrate (as NO_3) and an average nitrate concentration in the source area of 0.22 mg/L (as NO_3), the assimilative capacity for shallow groundwater at the fire training area was 1.07 mg/L (1,070 µg/L) BTEX in July 1995.

Nitrate concentrations in July 1995 were also reduced in the suspected source area at the RAPCON site. With an average background concentration (taken from temporary monitoring points GP-1 through GP-3) of 1.54 mg/L nitrate (as NO_3) and an average nitrate concentration in the suspected source area and downgradient from the source area (taken from temporary monitoring points GP-9 and FT01-FD9) of <0.05 mg/L of nitrate (as NO_3), the assimilative capacity for shallow groundwater at the RAPCON site is 1.34 mg/L BTEX.

4.4.2.3 Soluble Manganese

Soluble manganese (Mn^{2+}) concentrations were measured in groundwater samples collected in September 1994. Table 4.7 summarizes soluble manganese concentrations, which ranged from <0.1 to 0.9 mg/L. Figure 4.14 is an isopleth map showing the areal extent of soluble manganese in groundwater in September 1994. Comparison of Figure 4.14 and 4.4 shows graphically that the area of soluble manganese coincides with the BTEX plume originating at FT01. The highest soluble manganese concentration was detected at 0.9 mg/L at ESMW-1A in the center of the former fire training pit.

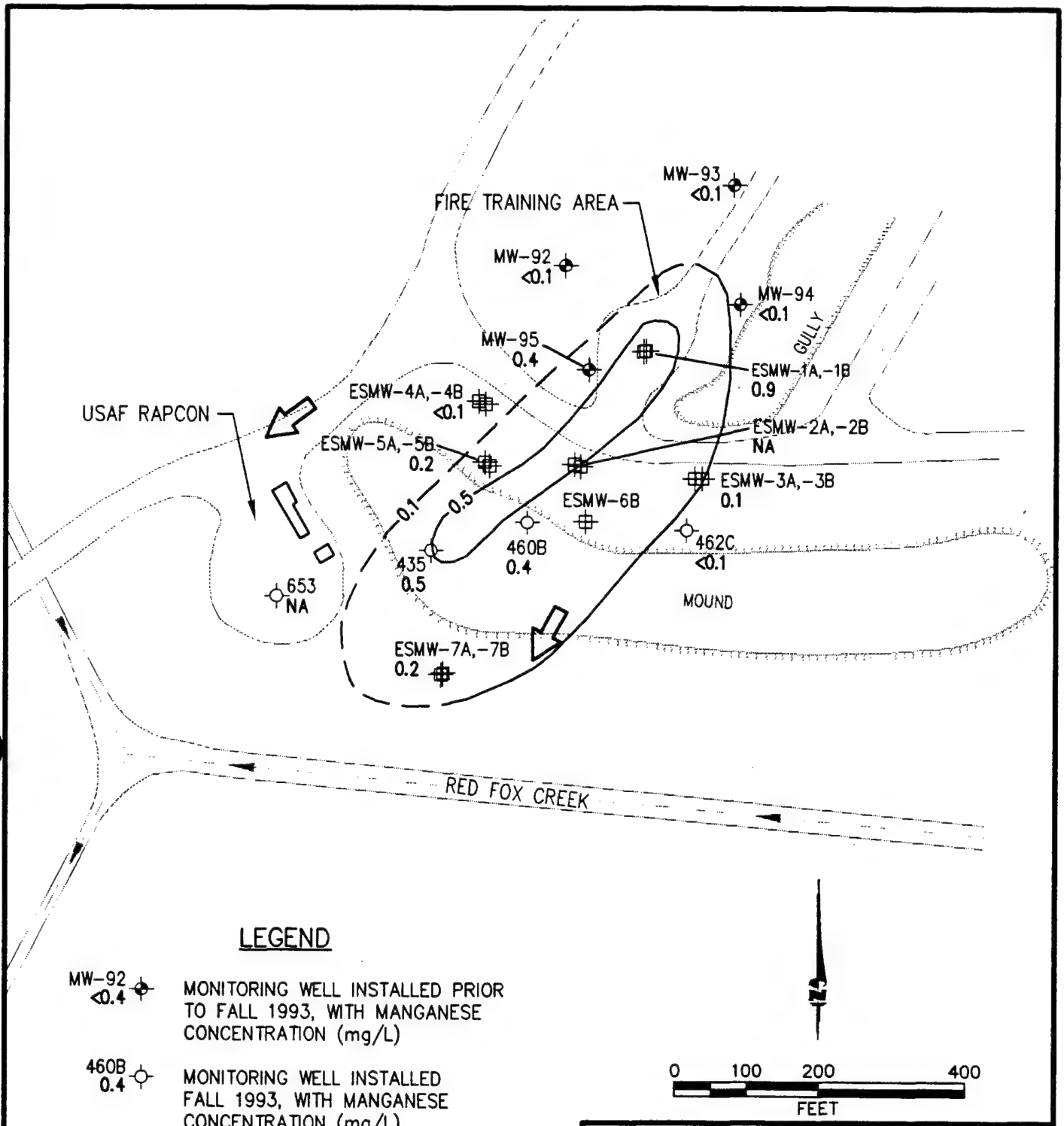

FIGURE 4.14

MANGANESE ISOPLETH MAP FOR SHALLOW GROUNDWATER (SEPTEMBER 1994)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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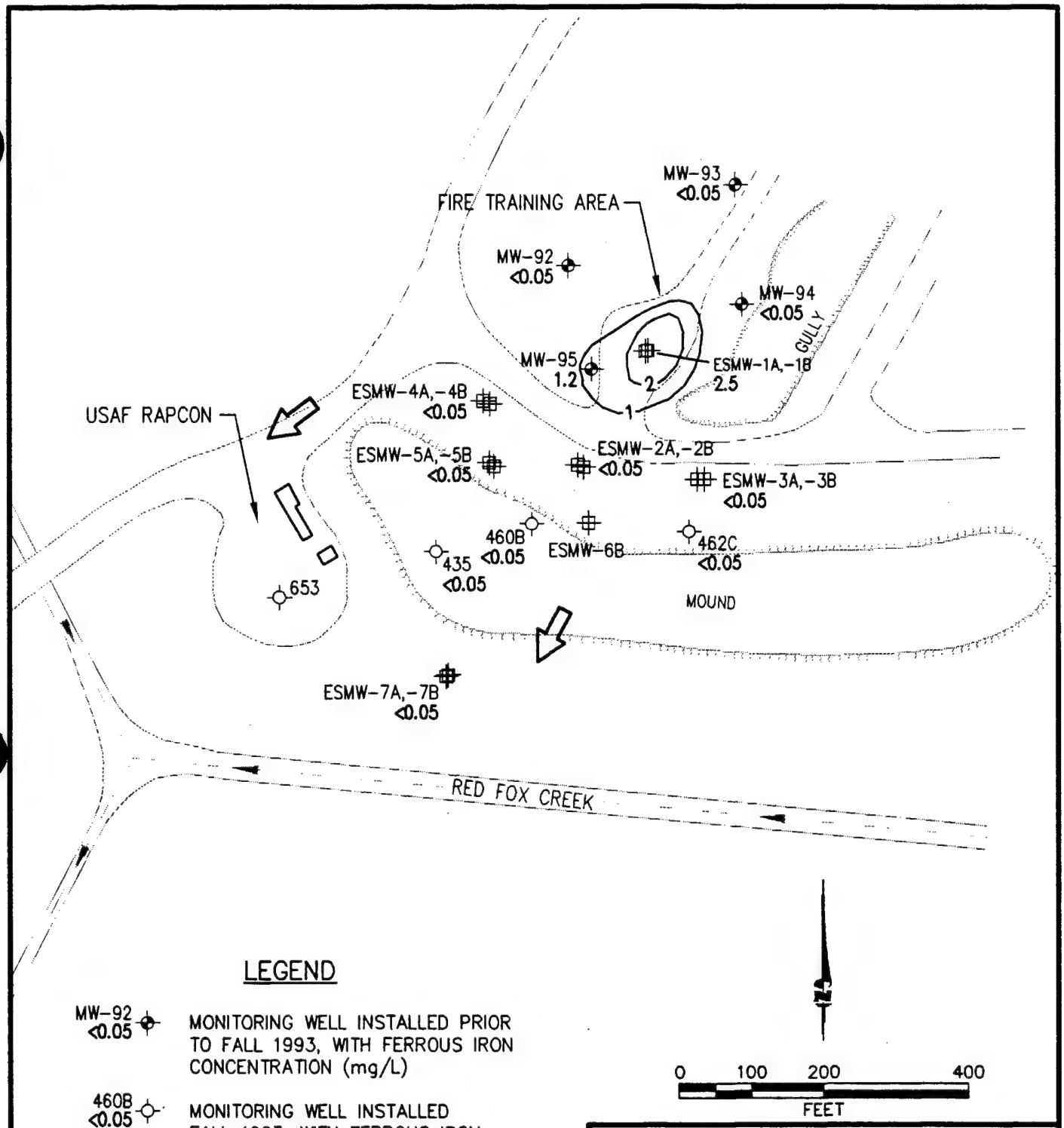
The stoichiometry of BTEX oxidation to carbon dioxide, soluble manganese, and water by manganese reduction through anaerobic microbial biodegradation is presented in Table 4.6. On average, 19 moles of manganese are required to metabolize one mole of total BTEX. Conversely, an average of 19 moles of soluble manganese are produced for each mole of total BTEX consumed. On a mass basis, this translates to approximately 11.0 mg of soluble manganese produced for each 1 mg of total BTEX metabolized. Given a background soluble manganese concentration of <0.1 mg/L (taken from monitoring wells MW-92, MW-93, and MW-94) and a maximum detected soluble manganese concentration in the source area of 0.9 mg/L, the shallow groundwater has the capacity to assimilate approximately 0.07 mg/L (70 µg/L) of total BTEX through manganese reduction. This is a conservative estimate of the assimilative capacity of soluble manganese because this calculation is based on observed soluble manganese concentrations and not on the amount of manganese dioxide available in the aquifer and solid soil matrix. Although a pattern of increased manganese with the presence of dissolved BTEX exists, the overall manganese assimilative capacity is very low, and manganese reduction is not considered to be an important biodegradation mechanism at the site.

4.4.2.4 Ferrous Iron

Fe^{2+} concentrations were measured in groundwater samples collected in September 1994 and July 1995. Table 4.7 summarizes ferrous iron concentrations. Ferrous iron concentrations ranged from <0.05 to 2.5 mg/L in September 1994, and from <0.1 to 15.0 mg/L in July 1995. Figures 4.15 and 4.16 are isopleth maps showing the areal extent of ferrous iron in groundwater in September 1994 and July 1995, respectively. Comparison of Figures 4.4 and 4.5 with Figures 4.15 and 4.16 shows graphically that elevated ferrous iron concentrations were observed in the source area at the fire training area in both sampling years and at the RAPCON site in July 1995. This suggests that ferric iron hydroxide (Fe^{3+}) is being reduced to ferrous iron during biodegradation of BTEX compounds.

The stoichiometry of BTEX oxidation to carbon dioxide, ferrous iron, and water by iron reduction through anaerobic microbial biodegradation is presented in Table 4.6. On average, 37.5 moles of ferric iron hydroxide are required to metabolize one mole of total BTEX. Conversely, an average of 37.5 moles of ferrous iron are produced for each mole of total BTEX consumed. On a mass basis, this translates to approximately 21.8 mg ferrous iron produced for each 1 mg of total BTEX metabolized. The shallow groundwater for the fire training area in September 1994 had a background ferrous iron concentration of <0.05 mg/L (taken from monitoring wells MW-92 through MW-94) and a maximum detected ferrous iron concentration of 2.5 mg/L (taken from monitoring well ESMW-1A), for an assimilative capacity of approximately 0.11 mg/L (110 µg/L) of total BTEX through iron reduction. This assimilative capacity estimate compares closely to the assimilative capacity estimate of 0.13 mg/L calculated from July 1995 data using an average background ferrous iron concentration of <0.1 mg/L and a maximum detected ferrous iron concentration of 3.0 mg/L.

Higher iron utilization was observed at the RAPCON site in July 1995. With a background ferrous iron concentration of <0.1 (taken from temporary monitoring points



LEGEND

MW-92 <0.05 — MONITORING WELL INSTALLED PRIOR TO FALL 1993, WITH FERROUS IRON CONCENTRATION (mg/L)

460B <0.05 — MONITORING WELL INSTALLED FALL 1993, WITH FERROUS IRON CONCENTRATION (mg/L)

ESMW-1A <0.05 — MONITORING WELL INSTALLED SEPTEMBER 1994, WITH FERROUS IRON CONCENTRATION (mg/L)

1 — LINE OF EQUAL FERROUS IRON CONCENTRATION (mg/L) (DASHED WHERE INFERRED)

ESTIMATED GROUNDWATER FLOW DIRECTION

N

0 100 200 400

FEET

FIGURE 4.15

FERROUS IRON ISOPLETH MAP FOR SHALLOW GROUNDWATER (SEPTEMBER 1994)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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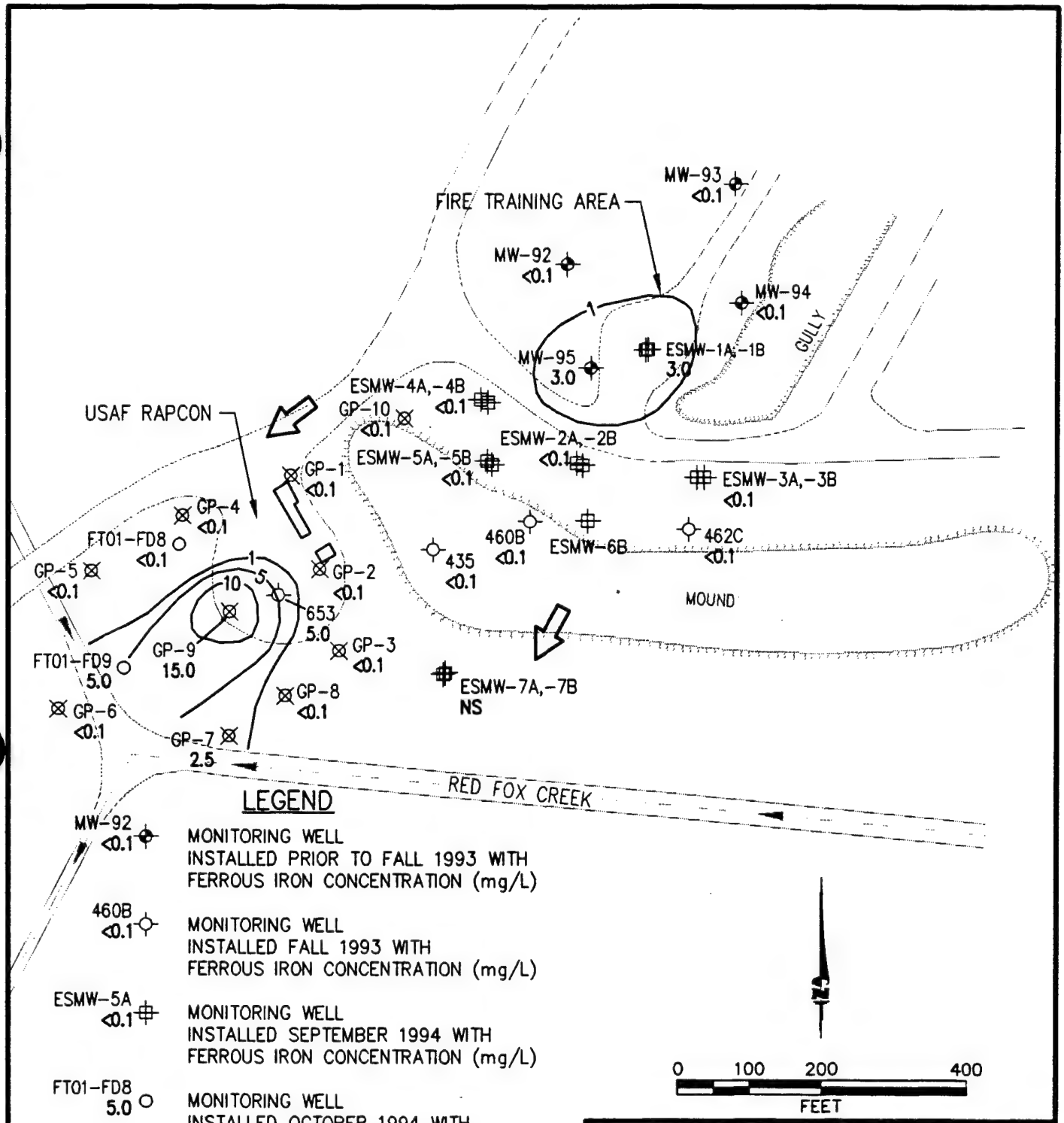

FIGURE 4.16

FERROUS IRON ISOPLETH MAP FOR SHALLOW GROUNDWATER (JULY 1995)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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GP-2 through GP-4) and a maximum detected ferrous iron concentration of 15 mg/L (taken from temporary monitoring point GP-9), the assimilative capacity for iron reduction at the RAPCON site was estimated at 0.68 mg/L (680 µg/L) of BTEX. The assimilative capacity estimates for iron reduction in September 1994 and July 1995 are conservative because the calculations were based on observed ferrous iron concentrations and not on the amount of ferric hydroxide available in the aquifer and solid soil matrix. Therefore, estimated iron assimilative capacities could be much higher.

Recent evidence suggests that the reduction of ferric iron to ferrous iron cannot proceed at all without microbial mediation (Lovley and Phillips, 1988; Lovley *et al.,* 1991; Chapelle, 1993). None of the common organic compounds found in low-temperature, neutral, reducing groundwater could reduce ferric oxyhydroxides to ferrous iron under sterile laboratory conditions (Lovley *et al.,* 1991). This means that the reduction of ferric iron requires microbial mediation by microorganisms with the appropriate enzymatic capabilities. Because the reduction of ferric iron cannot proceed without microbial intervention, the elevated concentrations of ferrous iron that were measured in the contaminated groundwater at the site are very strong indicators of microbial activity.

4.4.2.5 Sulfate

Sulfate concentrations were measured in groundwater samples collected in September 1994 and July 1995. Table 4.7 summarizes measured sulfate concentrations. Sulfate concentrations ranged from <0.5 to 6.91 mg/L in September 1994, and from <0.5 to 5.85 mg/L in July 1995. The stoichiometry of BTEX mineralization to carbon dioxide, sulfur, and water by sulfate reduction through anaerobic microbial biodegradation is presented in Table 4.6. The average mass ratio of sulfate to total BTEX is approximately 4.7 to 1. This translates to the mineralization of approximately 0.21 mg of total BTEX for every 1.0 mg of sulfate consumed.

The distribution of sulfate concentrations in the study area did not reflect a clear inverse relationship of reduced sulfate concentrations with increased BTEX concentrations. Based on the lack of a definitive trend of sulfate reduction for both September 1994 and July 1995 data (Table 4.7), sulfate is not considered to be an important electron acceptor at the fire training area or the RAPCON site.

4.4.2.6 Methane in Groundwater

Methane concentrations were measured in groundwater samples collected in September 1994 and July 1995. Table 4.7 summarizes measured methane concentrations. Methane concentrations ranged from <0.001 to 0.186 mg/L in September 1994 and from <0.001 to 0.390 mg/L in July 1995. The stoichiometry of BTEX oxidation to carbon dioxide and methane by methanogenesis is presented in Table 4.6. On average, approximately 1 mg of total BTEX is degraded for every 0.78 mg of methane produced.

Methane concentrations across the study area were low and not distributed in a clear pattern. Based on the low methane concentrations in groundwater and the absence of definitive trends in methane production, methanogenesis is not considered to be an important anaerobic biodegradation process at Site FT01 or the RAPCON site.

Furthermore, the lack of methanogenic biodegradation processes also suggests an absence of the reductive dehalogenation of TCE, which is most prevalent under methanogenic conditions (Bouwer, 1994).

4.4.2.7 Reduction/Oxidation Potential

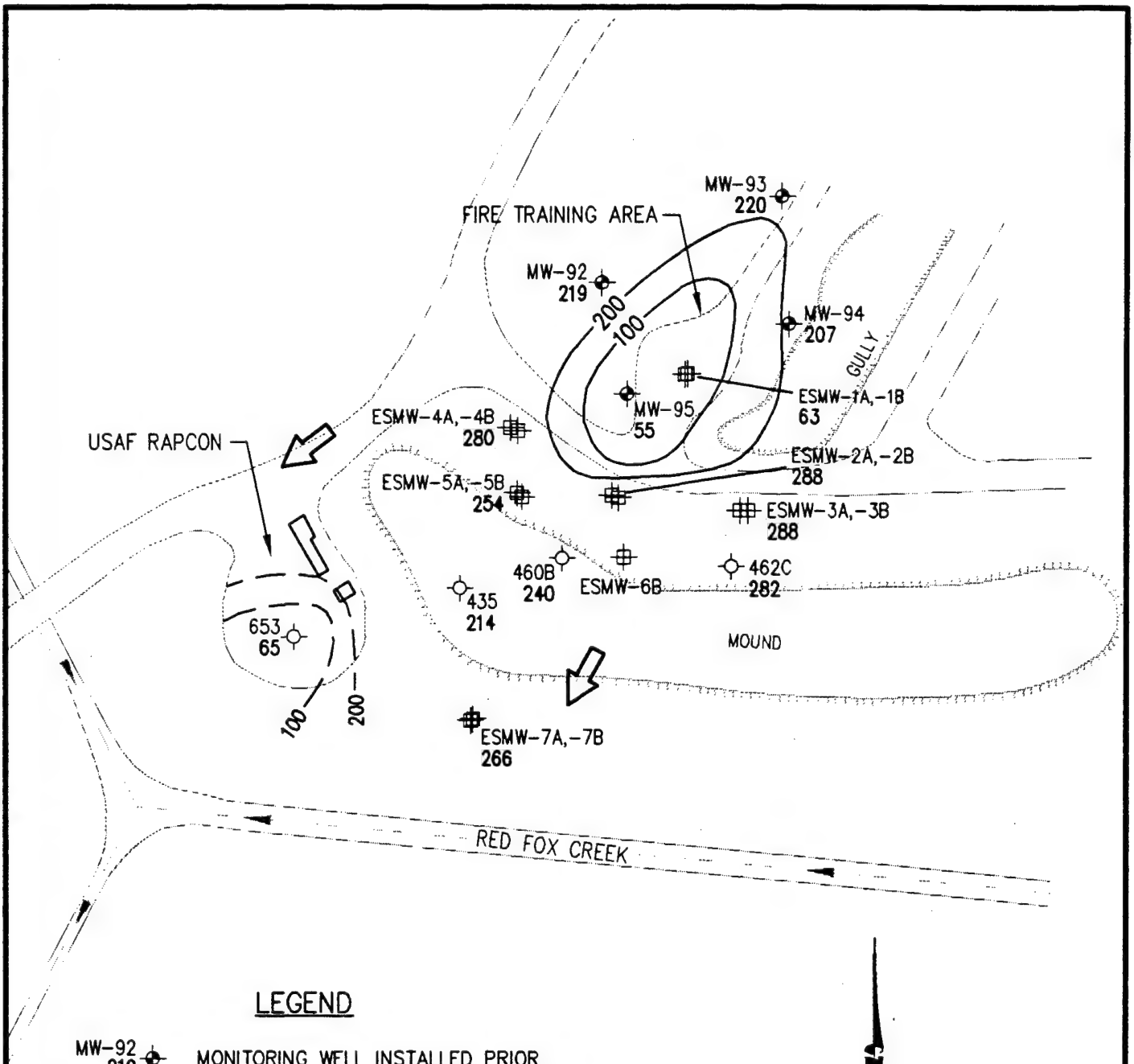
Redox potentials were measured at groundwater monitoring wells and points in September 1994 and July 1995. Redox potential is a measure of the relative tendency of a solution to accept or transfer electrons. The redox potential ranged from 55 millivolts (mV) to 297 mV in September 1994, and from -65 mV to 260 mV in July 1995. Table 4.7 summarizes available redox potential data. The areal extent of redox potentials is illustrated graphically on Figures 4.17 and Figure 4.18. The redox potentials of a groundwater system depend in part on which electron acceptors are being reduced by microbes during BTEX oxidation. Areas at the site with low redox potentials appear to coincide with variable areas of elevated BTEX contamination, TPH contamination, decreased oxygen, decreased nitrate, elevated soluble manganese, and elevated ferrous iron (compare Figures 4.17 and 4.28 with Figures 4.4 and 4.5 and 4.8 through 4.16).

In July 1995, the redox potentials measured at Site FT01 were elevated above the theoretical redox potential required for iron reduction processes (Norris *et al.*, 1994), although limited iron-reducing processes observed through ferrous iron production were occurring at the fire training area. This discrepancy is a common problem associated with measuring oxidizing potential using field instruments. It is likely that the platinum electrode probes are not sensitive to some of the redox reactions. Many authors have noted that field measured redox data alone cannot be used to reliably predict the electron acceptors that may be operating at a site (Stumm and Morgan, 1981; Godsey, 1994; and Lovley *et al.*, 1994). Integrating redox measurements with analytical data on reduced and oxidized chemical species allows a more thorough and reasonable interpretation of which electron acceptors are being used to biodegrade site contaminants.

4.4.2.8 Biogenic Carbon Dioxide and Alkalinity

Carbon dioxide is produced during the bioremediation of petroleum hydrocarbons. In aquifers that have carbonate minerals as part of the matrix, carbon dioxide forms carbonic acid, which dissolves these minerals, increasing the alkalinity of the groundwater. An increase in alkalinity (measured as $CaCO_3$) in an area with BTEX concentrations elevated above background conditions can be used to infer the amount of petroleum hydrocarbons destroyed through aerobic respiration, denitrification, ferric iron reduction, and sulfate reduction.

Free carbon dioxide was measured in groundwater samples collected in September 1994 and July 1995. These measurements are summarized in Table 4.7. Carbon dioxide evolution as indicated by above-background concentrations at monitoring well ESMW-1A in September 1994, and at monitoring point GP-9 in July 1995, is occurring as a result of combined aerobic and anaerobic biodegradation processes. A direct estimate of the aquifer assimilative capacity based on carbon dioxide evolution is not possible because of the complex carbonate/bicarbonate balance. However, total alkalinity (as $CaCO_3$) also was measured in groundwater samples collected in September 1994 and June 1995.



LEGEND

MW-92 219 — MONITORING WELL INSTALLED PRIOR TO FALL 1993, WITH REDOX POTENTIAL CONCENTRATION (mV)

460B 240 — MONITORING WELL INSTALLED FALL 1993, WITH REDOX POTENTIAL CONCENTRATION (mV)

ESMW-1A 254 — MONITORING WELL INSTALLED SEPTEMBER 1994, WITH REDOX POTENTIAL CONCENTRATION (mV)

300 — LINE OF EQUAL REDOX POTENTIAL CONCENTRATION (mV) (DASHED WHERE INFERRED) CONTOUR INTERVAL = 100 mV

ESTIMATED GROUNDWATER FLOW DIRECTION

N

0 100 200 400
FEET

FIGURE 4.17

REDOX POTENTIAL FOR SHALLOW GROUNDWATER (SEPTEMBER 1994)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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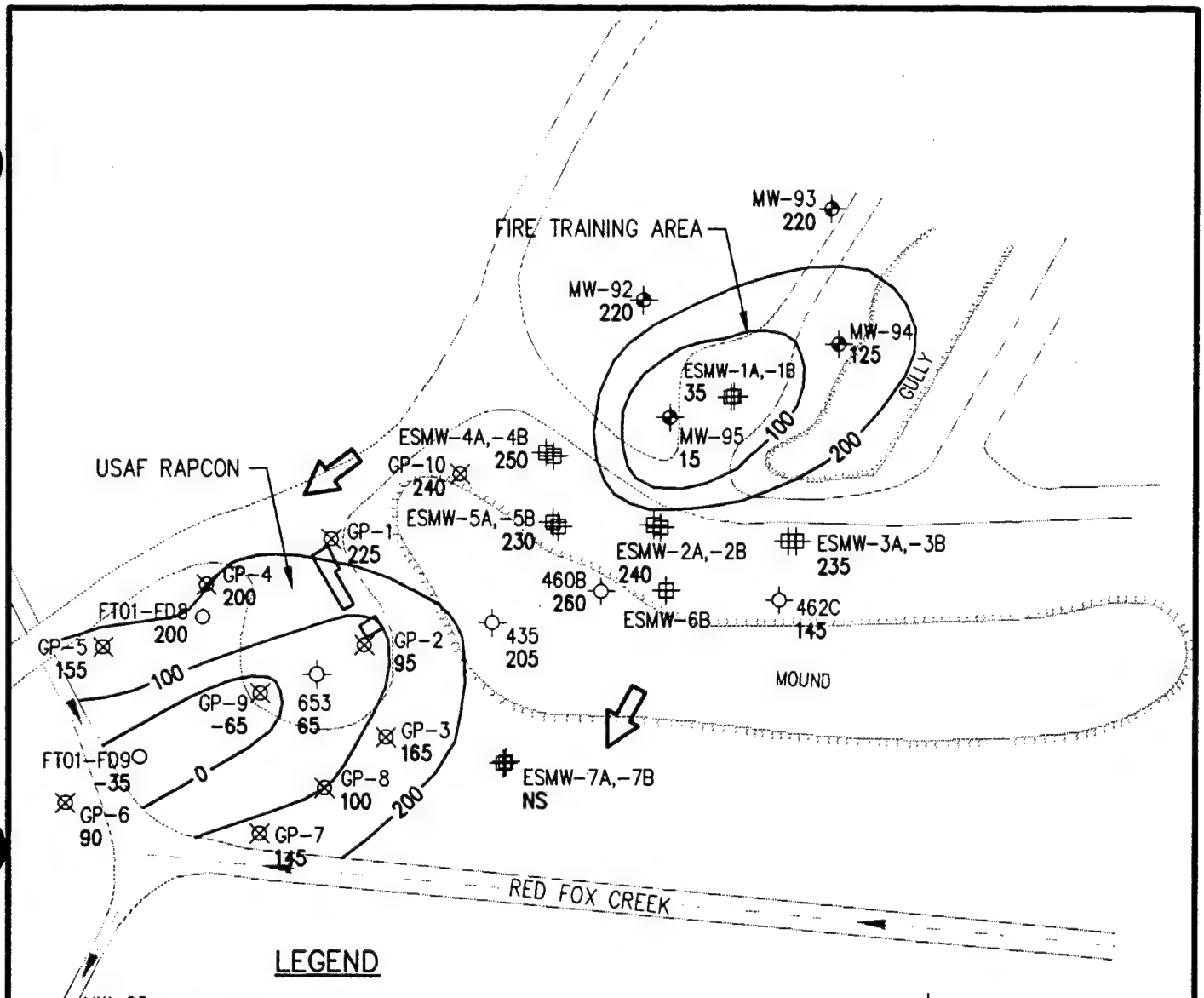

FIGURE 4.18

REDOX POTENTIAL ISOPLETH MAP FOR SHALLOW GROUNDWATER (JULY 1995)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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These measurements are summarized in Table 4.7 and illustrated in Figures 4.19 and 4.20. Alkalinity is a measure of the ability of groundwater to buffer changes in pH caused by the addition of biologically generated acids. Furthermore, alkalinity can be used in certain situations to estimate the assimilative capacity of groundwater (Wiedemeier *et al.*, 1995).

Total alkalinity varied from 9 mg/L to 132 mg/L as $CaCO_3$ in September 1994 and from 23 to 177 mg/L as $CaCO_3$ in July 1995 (Table 4.7). These ranges of alkalinity help to buffer potential changes in pH caused by biologically mediated BTEX oxidation reactions and suggests that aerobic and/or anaerobic biodegradation processes are occurring without detrimental shifts in pH. The mass ratio of alkalinity produced during oxidation of BTEX can be calculated. The molar ratio of alkalinity (as $CaCO_3$) produced during benzene oxidation via aerobic respiration, denitrification, ferric iron reduction, and sulfate reduction is given by:

$$C_6H_6 \rightarrow 6CO_2 \rightarrow 6CaCO_3$$

Therefore, 6 moles of $CaCO_3$ are produced during the metabolism of 1 mole of benzene. The resulting average mass ratio of alkalinity produced to total BTEX biodegraded is approximately 7.69 to 1. This translates to the mineralization of approximately 0.13 mg of total BTEX for every 1.0 mg of alkalinity produced. With an average background alkalinity (from monitoring wells MW-92 through MW-94) of 35 mg/L as $CaCO_3$ and alkalinity in the source area (at monitoring well ESMW-1A) of 132 mg/L as $CaCO_3$, the estimated assimilative capacity in September 1994 for shallow groundwater at the fire training area was approximately 12.6 mg/L of BTEX. Using identical background and source wells for data collected in July 1995, the estimated assimilative capacity for the fire training area decreased to approximately 5.3 mg/L of BTEX, with an average background alkalinity of 41 mg/L as $CaCO_3$ and a source area alkalinity of 82 mg/L as $CaCO_3$.

A significant change in alkalinity was observed downgradient of the RAPCON site at monitoring well FT01-FD9 in July 1995 (Figure 4.20). With an average background alkalinity of 30.3 mg/L as $CaCO_3$ (taken from temporary monitoring points GP-8, GP-9, and GP-4), and the maximum observed alkalinity downgradient from the source area of 177 mg/L as $CaCO_3$, (monitoring well FT01-FD9) the estimated assimilative capacity on the basis of alkalinity increase was 19.1 mg/L of BTEX. Trends of alkalinity increases in zones of high BTEX contamination are supportive of an environment amenable to biodegradation.

4.4.2.9 pH

The groundwater pH was measured for samples collected from monitoring points and monitoring wells in September 1994 and July 1995. These measurements are summarized in Table 4.7. The pH of a solution is the negative logarithm of the hydrogen ion concentration [H^+]. Groundwater pH ranged from 6.1 to 7.7 standard units in September 1994, and from 6.3 to 7.4 standard units in July 1995. These ranges of pH overlap the optimal range for most bacteria of 6 to 9 standard units (Atlas, 1988). The groundwater alkalinity provides the buffering capacity to maintain this pH range.

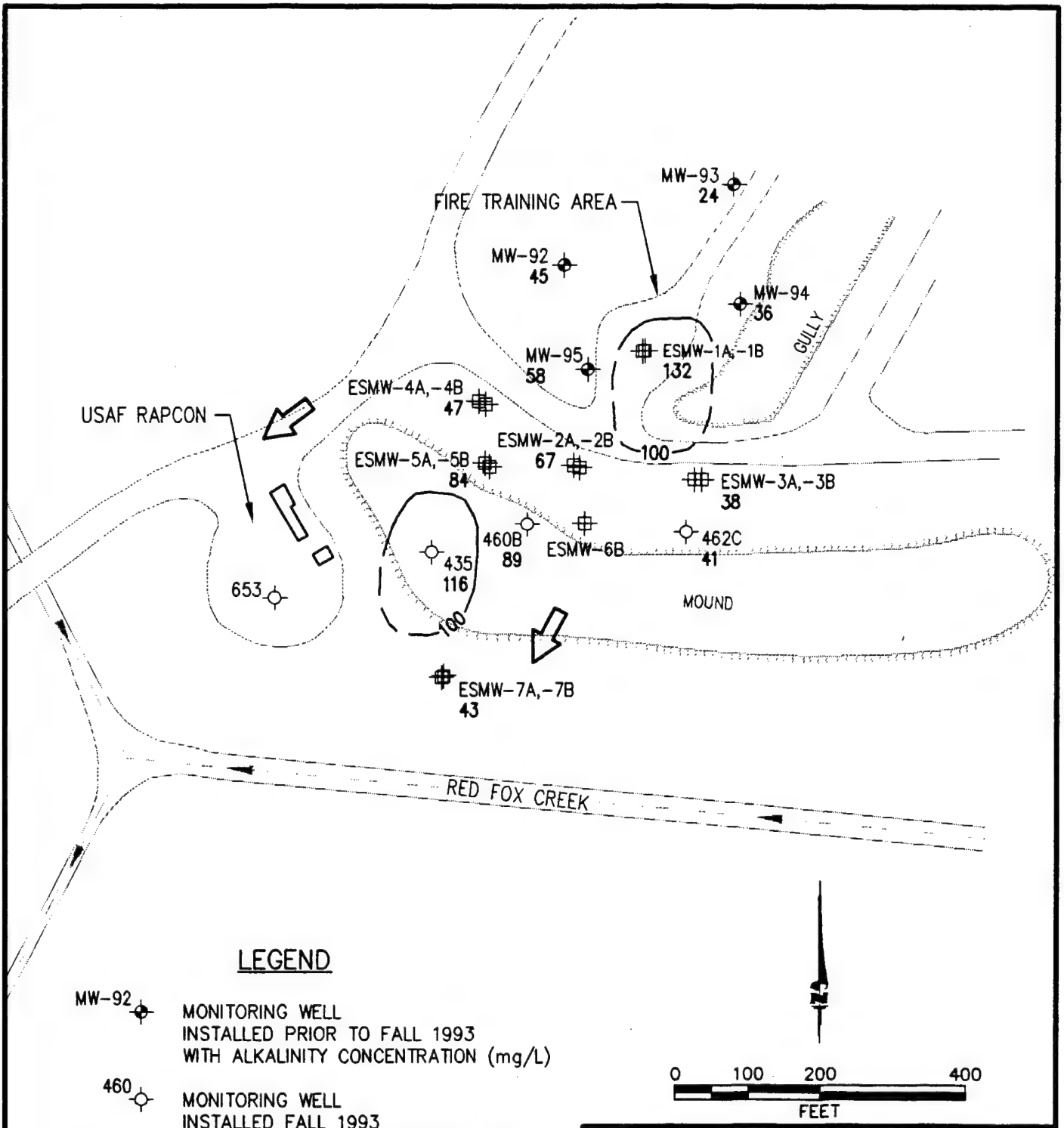

FIGURE 4.19

ALKALINITY IN SHALLOW GROUNDWATER (SEPTEMBER 1994)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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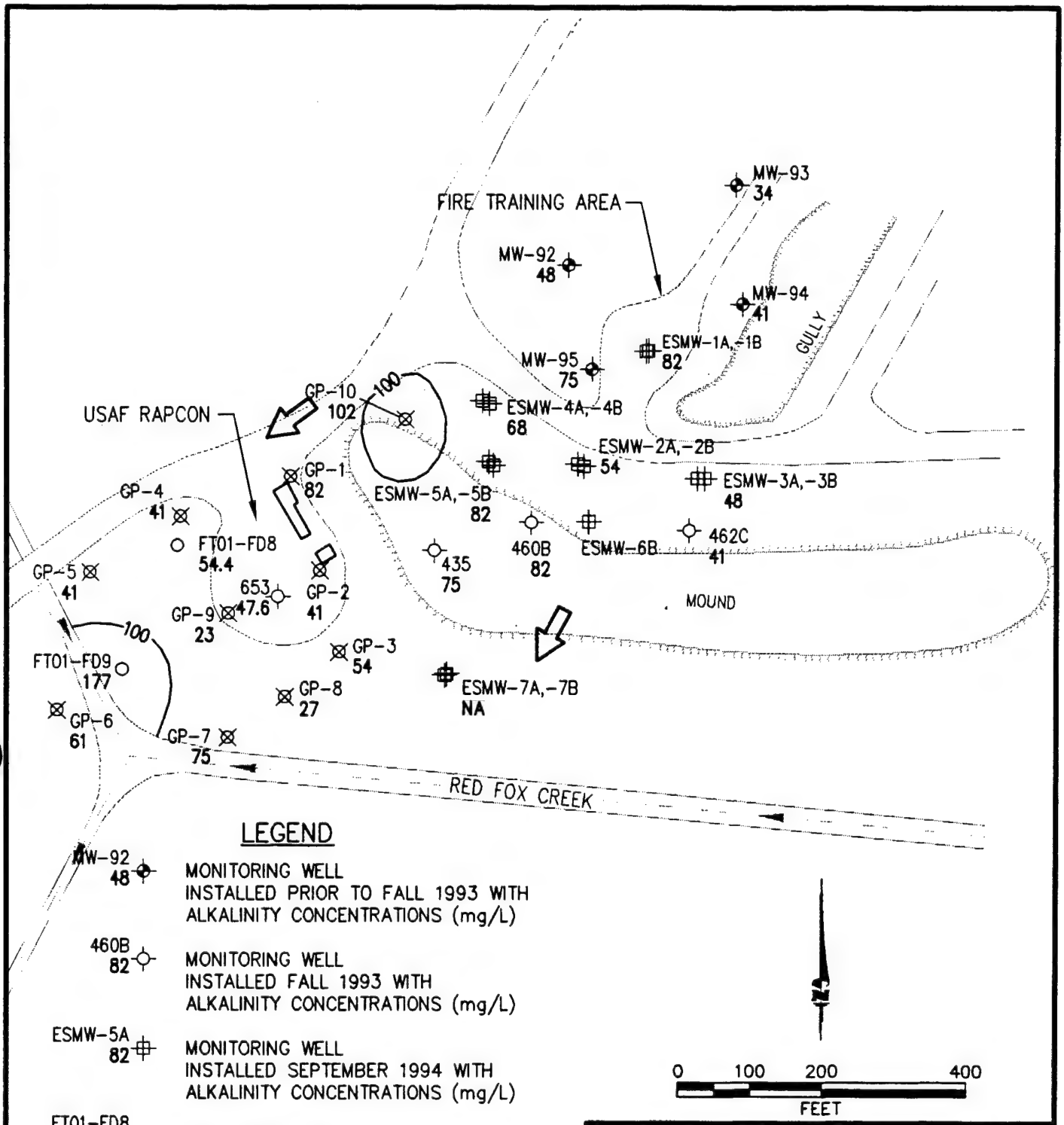

FIGURE 4.20

ALKALINITY ISOPLETH MAP FOR SHALLOW GROUNDWATER (JULY 1995)

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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4.4.2.10 Temperature

Groundwater temperature was measured at groundwater monitoring points and monitoring wells in September 1994 and July 1995. Table 4.7 summarizes groundwater temperature readings. Temperature affects the types and growth rates of bacteria that can be supported in the groundwater environment, with higher temperatures generally resulting in higher growth rates. Temperatures in the shallow aquifer varied from 5.0 degrees Celsius (°C) to 9.0°C, in September 1994, and from 2.5°C to 10.0°C in July 1995. These temperatures are colder than encountered in more temperate environments, but are within temperature ranges required for psychrophilic, hydrocarbon-degrading microorganisms to survive and function (Atlas & Bartha, 1987).

4.4.3 Discussion

Numerous laboratory and field studies have shown that hydrocarbon-degrading bacteria can participate in the degradation of many of the chemical components of jet fuel and gasoline, including the BTEX compounds (e.g., Jamison *et al.,* 1975; Atlas, 1981, 1984, and 1988; Gibson and Subramanian, 1984; Reinhard *et al.,* 1984; Young, 1984; Bartha, 1986; Wilson *et al.,* 1986, 1987, and 1990; Barker *et al.,* 1987; Baedecker *et al.,* 1988; Lee, 1988; Chiang *et al.,* 1989; Grbic-Galic, 1989 and 1990; Cozzarelli *et al.,* 1990; Leahy and Colewell, 1990; Altenschmidt and Fuchs, 1991; Alvarez and Vogel, 1991; Baedecker and Cozzarelli, 1991; Ball *et al.,* 1991; Bauman, 1991; Borden, 1991; Brown *et al.*, 1991; Edwards *et al.,* 1991 and 1992; Evans *et al.,* 1991a and 1991b; Haag *et al.,* 1991; Hutchins and Wilson, 1991; Hutchins *et al.,* 1991a and 1991b; Beller *et al.,* 1992; Bouwer, 1992; Edwards and Grbic-Galic, 1992; Thierrin *et al.,* 1992; Malone *et al.,* 1993; Davis *et al.,* 1994). Biodegradation of fuel hydrocarbons can occur when an indigenous population of hydrocarbon-degrading microorganisms is present in the aquifer and sufficient concentrations of electron acceptors, nutrients, and electron donors such as fuel hydrocarbons, are available to these organisms.

Comparison of BTEX, electron acceptor, and biodegradation byproduct isopleth maps presented earlier in this section provides strong qualitative evidence of the biodegradation of BTEX compounds. Isopleth maps suggest that three electron acceptors are particularly active in the biodegradation of BTEX compounds in the study area: oxygen, nitrate, and ferric iron (indicated by the presence of ferrous iron). Typically, zones of depleted oxygen, depleted nitrate, and elevated ferrous iron concentration coincide with elevated dissolved BTEX concentrations because of the preferred order of electron acceptor utilization as redox potentials decline. In the study area, the spatial distributions of electron acceptors, metabolic byproducts, and BTEX concentrations closely follow the expected trends as redox potentials declined.

Similar to BTEX compounds, chlorinated solvents can be transformed by biological processes (e.g., Bouwer *et al.*, 1981; Wilson and Wilson, 1985; Miller and Guengerich, 1982; Nelson *et al.*, 1986; Bouwer and Wright, 1988; Little *et al.*, 1988; Mayer *et al.*, 1988; Arciero *et al.*, 1989; Cline and Delfino, 1989; Freedman and Gosset, 1989; Folsom *et al.*, 1990; Harker and Kim, 1990; Alvarez-Cohen and McCarty, 1991a, 1991b; DeStefano *et al.*, 1991; Henry, 1991; McCarty *et al.*, 1992; Hartmans and de Bont, 1992; McCarty and Semprini, 1994; Vogel, 1994). Chlorinated VOCs may undergo intrinsic

bioremediation through three different pathways: use as an electron acceptor, use as an electron donor, or cometabolism. At a given site, one or all of these processes may be operating, although the use of chlorinated VOCs as electron acceptors is the most common. In addition, it is believed that TCE, the dominant chlorinated VOC at the site, cannot be used as an electron donor by microorganisms. Reductive dehalogenation has been demonstrated under nitrate- and sulfate-reducing conditions, but the most rapid biodegradation rates, affecting the widest range of chlorinated VOCs, occur under methanogenic conditions (Bouwer, 1994). However, sequential degradation products for TCE were not observed at the study area and methanogenic, or strongly reducing, conditions do not exist, which suggests that the reductive dehalogenation of TCE is not occurring. The cometabolism of TCE could potentially occur at the site; however, its occurrence has not been documented.

4.4.4 Expressed Assimilative Capacity

The data presented in the preceding sections suggest that mineralization of BTEX compounds is occurring through the microbially mediated processes of aerobic biodegradation, denitrification, and iron reduction. On the basis of the stoichiometry presented in Table 4.6 and observed background electron acceptors, the expressed BTEX assimilative capacity of groundwater at Site FT01 ranges from 2,510 to 1,810 µg/L in September 1994 and July 1995, respectively (Table 4.8). The expressed assimilative capacity for the RAPCON site in July 1995 was estimated at 4,710 µg/L (Table 4.8).

A closed system with 2 liters of water can be used to help visualize the physical meaning of assimilative capacity. Assume that the first liter contains no fuel hydrocarbons, but it contains fuel degrading microorganisms and has an assimilative capacity of exactly "*x*"µg of fuel hydrocarbons. The second liter has no assimilative capacity; however, it contains fuel hydrocarbons. As long as these 2 liters of water are kept separate, biodegradation of the fuel hydrocarbons will not occur. If these 2 liters are combined in a closed system, biodegradation will commence and continue until the fuel hydrocarbons are depleted, the electron acceptors are depleted, or the environment becomes acutely toxic to the fuel degrading microorganisms. Assuming a nonlethal environment, if fewer than "*x*" µg of fuel hydrocarbons were in the second liter, all of the fuel hydrocarbons will eventually degrade given a sufficient time; likewise, if greater than "x" µg of fuel hydrocarbons were in the second liter of water, only "*x*" µg of fuel hydrocarbons would ultimately degrade.

The groundwater beneath the study area is a part of an open system, which continually receives additional electron acceptors from upgradient flow and the percolation of precipitation. This means that the assimilative capacity is not fixed as it is in a closed system, and therefore cannot be compared directly to contaminant concentrations in the groundwater. Rather, the expressed assimilative capacity of groundwater is intended to serve as a qualitative tool. Although the expressed assimilative capacity at either site is lower than the highest measured total BTEX concentration observed in September 1994 or July 1995 (10,100 and 9,230 µg/L, respectively), the fate of BTEX in groundwater and the potential impact to receptors is dependent on the relationship between the kinetics of biodegradation and the solute transport velocity (Chapelle, 1994). The expressed assimilative capacity is a strong indicator that biodegradation is occurring; however, it is

TABLE 4.8
EXPRESSED ASSIMILATIVE CAPACITY OF SITE GROUNDWATER

FIRE TRAINING AREA 1 (FT01)

INTRINSIC REMEDIATION TS

KING SALMON AIRPORT, ALASKA

Electron Acceptor or Process	Expressed BTEX Assimilative Capacity, Site FT01, September 1994 (µg/L)	Expressed BTEX Assimilative Capacity, Site FT01, July 1995 (µg/L)	Expressed BTEX Assimilative Capacity, RAPCON Site, July 1995 (µg/L)
Dissolved Oxygen	1,910	610	2,690
Nitrate	490	1,070	1,340
Manganese Reduction	NA	NA	NA
Iron Reduction	410	130	680
Sulfate	NA	NA	NA
Methanogenesis	NA	NA	NA
Expressed Assimilative Capacity	2,510	1,810	4,710

not an indication that biodegradation will or will not proceed to completion before potential downgradient receptors are impacted.

Although geochemical indicators cannot be used to predict the rate of BTEX biodegradation, it is important to observe that BTEX concentrations decrease with increasing distance from the source area. Figures 4.4 and 4.5 illustrates that BTEX compounds emanating from the fire training pit are mostly attenuated within 500 feet downgradient from the source area. BTEX concentrations higher than 4 µg/L have not migrated beyond temporary monitoring point GP-2 (Figure 4.5), suggesting that BTEX compounds from the fire training pit are not reaching Red Fox Creek. However, Figure 4.5 illustrates that BTEX compounds emanating from the RAPCON site probably are impacting Red Fox Creek. Near the edge of the creek (at FT01-FD9), the fraction of benzene in total BTEX (8 percent) compared to the fraction of xylenes in BTEX (60 percent) is relatively low, whereas the same fractions near the source (GP-9) were more similar in magnitude (11 percent benzene vs. 36 percent xylenes). This trend contradicts theory which predicts that benzene will be the BTEX compound most recalcitrant to biodegradation and most mobile in groundwater, and should therefore comprise an increasingly higher percentage of the BTEX in groundwater samples collected increasingly downgradient from the source area. However, benzene has been observed to biodegrade at rates faster than ethylbenzene or xylenes in sandy aquifers at Myrtle Beach AFB in South Carolina (Parsons ES, 1995b) and at Carswell AFB in Texas (Parsons ES, 1995d). It is possible that the molecular weight of a degradable compound is more important than molecular structure in some instances, thereby causing compounds such as ethylbenzene and xylene(s) to become more biologically recalcitrant than benzene. The apparent susceptibility of benzene to greater intrinsic bioremediation rates, combined with other natural attenuation mechanisms, result in a 70-percent decrease in benzene

concentrations while BTEX concentrations decrease 59 percent between temporary monitoring point GP-9 and monitoring well FT01-FD9 (near Red Fox Creek) (Tables 4.3).

At Site FT01, natural attenuation mechanisms appear to be removing BTEX contamination before discharge to Red Fox Creek. However, natural attenuation mechanisms are only partially removing BTEX contamination from the RAPCON site before discharge to Red Fox Creek. Currently, an undefined mass of LNAPL is suspected to be continually replenishing dissolved BTEX concentrations at the RAPCON site. Sampling and analysis has documented that groundwater with total BTEX concentrations as high as 3,800 µg/L is discharging into Red Fox Creek (Figure 4.5). Despite the possibility of limited attenuation of TCE by cometabolism, TCE continues to discharge to Red Fox Creek at concentrations as high as 636 µg/L. Natural attenuation of BTEX and/or TCE in groundwater should, therefore, be considered only as one component of the remedial solution to be implemented at the study area as discussed in Section 6.

SECTION 5

GROUNDWATER MODEL

5.1 GENERAL OVERVIEW AND MODEL DESCRIPTION

In order to help estimate attenuation rates for dissolved BTEX compounds at the Fire Training Area and the RAPCON site and to help predict the future migration of these compounds, Parsons ES modeled shallow groundwater flow and the fate and transport of the dissolved BTEX plume. The modeling effort had three primary objectives: 1) to predict the future extent and concentration of the dissolved contaminant plume by modeling the combined effects of advection, dispersion, sorption, and biodegradation; 2) to assess the potential for downgradient receptors to be exposed to contaminants at concentrations above regulatory levels of concern; and 3) to provide technical support for the natural attenuation remedial option at post-modeling regulatory negotiations. The model was developed using site-specific data and conservative assumptions about governing physical and chemical processes. Because of the conservative nature of model input, the reduction in contaminant mass caused by natural attenuation may exceed model predictions. The modeling effort did not include predictions to determine the future extent and concentration of the TCE plume emanating from the RAPCON site, which is outside of the scope of this TS. Furthermore, this analysis is not intended to represent a baseline assessment of potential risks posed by site contamination.

The Bioplume II code was used to estimate the potential for dissolved BTEX migration and attenuation by natural physical, chemical, and biological mechanisms operating at the fire training area and the RAPCON site, including advection, dispersion, sorption, and biodegradation. The model is based upon the US Geological Survey (USGS) Method of Characteristics (MOC) two-dimensional (2-D) solute transport model of Konikow and Bredehoeft (1978). The model was modified by researchers at Rice University to include an aerobic biodegradation component that is activated by a superimposed DO plume. Incorporating the work of Borden and Bedient (1986), the model assumes a reaction between DO and BTEX that is instantaneous relative to the advective groundwater velocity. Bioplume II solves the USGS 2-D solute transport equation twice, once for hydrocarbon concentrations in the aquifer and once for a DO plume. The two plumes are combined using superposition at every particle move to simulate the instantaneous, biologically-mediated, reaction between hydrocarbons and oxygen.

In recent years it has become apparent that anaerobic processes such as denitrification, iron reduction, sulfate reduction, and methanogenesis can be important BTEX degradation mechanisms (Grbic′-Galic′, 1990; Beller *et al.*, 1992; Edwards *et al.*, 1992; Edwards and Grbic′-Galic′, 1992, Grbic′-Galic′ and Vogel, 1987; Lovely *et al.*, 1989;

Hutchins, 1991). Because there is evidence that anaerobic biodegradation processes are occurring at the study area, these processes were accounted for during Bioplume II modeling using a first-order anaerobic decay coefficient. The following subsections discuss in more detail the model setup, input parameters and assumptions, model calibration, and simulation results.

5.2 CONCEPTUAL MODEL DESIGN AND ASSUMPTIONS

Prior to developing a groundwater model, it is important to determine if sufficient data are available to provide a reasonable estimate of aquifer conditions. In addition, it is important to ensure that any limiting assumptions can be justified. The most important assumption made when using the Bioplume II model is that electron-acceptor-limited biodegradation is occurring at the site. The Bioplume II model assumes that the limiting factors for fuel hydrocarbon biodegradation are: 1) the presence of an indigenous, hydrocarbon-degrading microbial population, and 2) sufficient background electron acceptor concentrations. Data and information presented in Section 4 suggest that DO, nitrate, and ferric iron are being used as the primary electron acceptors via the microbially mediated processes of aerobic respiration, denitrification, and iron reduction, respectively. The model assumes that DO is the only electron acceptor that reacts instantaneously with the BTEX plume; anaerobic biodegradation of petroleum hydrocarbons is simulated using a first-order decay constant. Selection of this constant is discussed in Section 5.3.5.

On the basis of the data presented in Section 3, the surficial aquifer through which the dissolved BTEX is migrating was conceptualized and modeled as a shallow unconfined aquifer composed primarily of fine- to medium-grained sand (Figures 3.3 and 3.4). The use of a 2-D model is appropriate at this site because the surficial aquifer appears to be relatively homogenous, and groundwater quality data suggest that the dissolved BTEX contamination has not migrated a significant distance vertically. Lithologic data obtained during this study and previous investigations (EMCON, 1994a) (Section 3) suggest that this aquifer is bounded vertically by an aquitard consisting of clayey silt to silty clay; the average saturated thickness of the surficial aquifer at the study area was estimated to be between 30 to 35 feet. The average thickness of the dissolved BTEX plume was estimated to be approximately 25, based on measured BTEX concentrations in the deep monitoring well ESMW-2B (Section 4.5.1.1); therefore, this was the value used for the aquifer thickness in the Bioplume model. Groundwater enters the site via inflow from the northeast, and, after migrating through the primary contaminant source areas, migrates in a southwesterly direction toward Red Fox Creek. The shallow groundwater system beneath the study area is also recharged by infiltrating precipitation. The low magnitude of dissolved BTEX concentrations detected downgradient from (southwest of) Red Fox Creek suggests that the majority of the plume discharges to the creek. This observation is supported by hydrocarbon sheens observed in the creek and by information presented by Strack (1989), who provides an example in which a stream penetrates one-tenth of the aquifer thickness and captures approximately 94 percent of the groundwater flow from its upgradient side. Given the lack of data regarding the nature of the stream-aquifer interactions in the model area, this assumption that the streams are fully penetrating seems reasonable. However, during dry periods when the water table is relatively low, it

is conceivable that all or a portion of the dissolved contamination migrates beneath the creek.

Available contaminant concentration data indicate that the dissolved BTEX plume emanating from the fire training area migrates toward Red Fox Creek, and is not significantly affected by the localized irregularities in the water table gradient observed in 1994 and 1995, and described in Section 3.3.2. Therefore, these irregularities were not incorporated into the Bioplume II model. Rather, the water table surface as simulated by the model slopes continuously toward the creek.

Historical information indicates that contamination was introduced into the subsurface at the fire training area beginning in 1980. The majority of contaminated soils at Site FT01 were excavated in 1995 (EMCON, 1996a). Mobile LNAPL has never been detected in monitoring wells at Site FT01 or the RAPCON site. However, a sheen was reportedly observed in Red Fox Creek and in subsurface soils near Red Fox Creek at monitoring well FT01-FD9 (see Section 4.4.2), and an approximately 0.25-inch-thick layer of mobile LNAPL was noted on the groundwater surface in the fire training pit excavation in 1995 (see Section 4.1). The source(s) and precise location of soil contamination at the RAPCON site are not known. However, the presence of soil contamination at this site can be inferred from groundwater quality data. Residual LNAPL remaining at both sites provides a continuing source of dissolved BTEX may increase the time required to remediate the groundwater. Because both Site FT01 and the RAPCON site are inactive, additional fuel releases are not expected at either site.

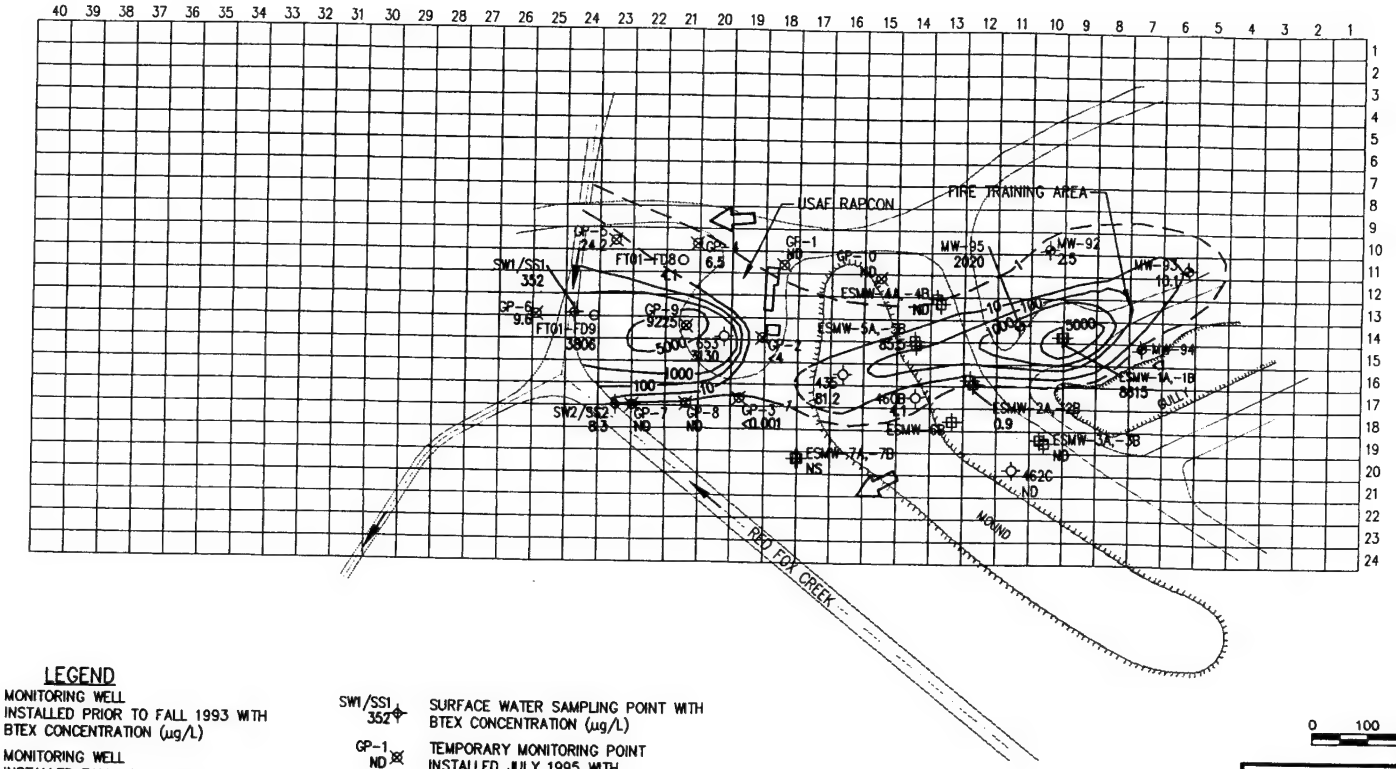
5.3 INITIAL MODEL SETUP

Where possible, the initial setup for this model was based on site-specific data. Where site-specific data were not available (e.g., effective porosity), reasonable assumptions were made on the basis of widely accepted literature values for materials similar to those found in the shallow aquifer. The following sections describe the basic model setup. Those Bioplume II model parameters that were varied during model calibration are discussed in Section 5.4.

5.3.1 Grid Design and Boundary Conditions

The Bioplume II model used in this study was modified to allow the use of up to 50 columns and 100 rows. The dimension of each column and row can range from 0.1 to 999.9 feet. A 24- by 40-cell grid was used to model the combined fire training/RAPCON study area. Each grid cell was 40 feet wide by 60 feet long. The grid was oriented with the longest dimension parallel to the overall direction of groundwater flow and dissolved BTEX migration. The model grid covers an area of 2,304,000 square feet, or approximately 53 acres. The full extent of the model grid is indicated on Figure 5.1. The grid was extended a substantial distance southwest of (downgradient from) Red Fox Creek to allow simulation of potential contaminant underflow beneath the creek.

Model boundaries are mathematical statements that represent hydrogeologic boundaries, such as areas of specified head (e.g., surface water bodies or contour lines of constant hydraulic head) or specified flux. Hydrogeologic boundaries are represented by



LEGEND

- MW-92 2.5 — MONITORING WELL INSTALLED PRIOR TO FALL 1993 WITH BTEX CONCENTRATION (µg/L)
- 460B 4.1 — MONITORING WELL INSTALLED FALL 1993 WITH BTEX CONCENTRATION (µg/L)
- ESMW-5A 85.5 — MONITORING WELL INSTALLED SEPTEMBER 1994 WITH BTEX CONCENTRATION (µg/L)
- FT01-FD8 3806 — MONITORING WELL INSTALLED OCTOBER 1994 WITH BTEX CONCENTRATION (µg/L)
- SW1/SS1 352 — SURFACE WATER SAMPLING POINT WITH BTEX CONCENTRATION (µg/L)
- GP-1 ND — TEMPORARY MONITORING POINT INSTALLED JULY 1995 WITH BTEX CONCENTRATION (µg/L)
- NS — NOT SAMPLED
- ND — NOT DETECTED
- ESTIMATED GROUNDWATER FLOW DIRECTION
- —100— LINE OF EQUAL BTEX CONCENTRATION (µg/L) DASHED WHERE INFERRED

NOTE:
ISOPLETHS CONSTRUCTED USING HIGHEST BTEX CONCENTRATION DETECTED IN NESTED WELLS

FIGURE 5.1

MODEL GRID SUPERIMPOSED ON DISSOLVED BTEX ISOPLETHS

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

L:\45011\DRAWINGS\FT001\96DN0259, 05/16/96 at 11:58

three mathematical statements that describe the hydraulic head at the model boundaries. These include:

- Specified-head boundaries (Dirichlet condition) for which the head is determined as a function of location and time only. Surface water bodies typically exhibit constant-head conditions. Specified-head boundaries are expressed mathematically as:

$$Head = f(x, y, z, t)$$

- Specified-flow boundaries (Neumann conditions) for which the mathematical description of the flux across the boundary is given. The flux is defined as a volumetric flow rate per unit area cubic feet per square foot per day [e.g., ($ft^3/ft^2/day$)]. No-flow boundaries are a special type of specified-flow boundary and are set by specifying the flux to be zero. Examples of no-flow boundaries include groundwater divides and impermeable hydrostratigraphic units. Specified-flux boundaries are expressed mathematically as:

$$Flux = f(x, y, z, t)$$

- Head-dependent flow boundaries (Cauchy or mixed-boundary conditions) where the flux across the boundary is calculated from a given boundary head value. This type of flow boundary is sometimes referred to as a mixed-boundary condition because it is a combination of a specified-head boundary and a specified-flow boundary. Head-dependent flow boundaries are used to model leakage across semipermeable boundaries. Head-dependent flow boundaries are expressed mathematically as (Bear, 1979):

$$Flux = \frac{(H_0 - H)K'}{B'}$$

where: H = Head in the zone being modeled (generally the zone containing the contaminant plume),

H_0 = Head in external zone (separated from plume by semipermeable layer),

K' = Hydraulic conductivity of semipermeable layer, and

B' = Thickness of semipermeable layer.

Natural hydraulic boundaries are modeled using a combination of the three types of model boundary conditions listed above. When possible, hydrologic boundaries such as surface water bodies, groundwater divides, or hydrologic barriers should coincide with the perimeter of the model. In areas lacking obvious hydrologic boundaries, specified-head or specified-flux boundaries can be specified at the model perimeter if the boundaries are far enough removed from the contaminant plume that transport calculations are not affected. Bioplume II requires the entire model domain to be

bounded by zero-flux cells (also known as no-flow cells), with other boundary conditions established within the subdomain specified by the no-flow cells.

Specified-head boundaries for the model were set at Red Fox Creek and on the northeastern perimeter of the model grid to simulate the southwesterly groundwater flow observed in the study area. The hydraulic head along Red Fox Creek was estimated to be 47.49 to 47.62 feet above mllw. The hydraulic head at the northeastern model boundary was estimated to range from 51.09 to 51.52 feet above mllw. These constant-head cells were placed far enough away from the Site FT01 BTEX plume to avoid potential boundary interferences. Placement of the constant-head boundary along Red Fox Creek near the RAPCON plume was unavoidable due to the proximity of this plume to the creek. The area south and southeast of the creek was inactive (all cells assigned a no-flow status) in order to simulate the scenario where the groundwater discharges to the creek.

Except for the boundary cells in model grid rows 2 through 5 (Figure 5.1), which were assigned a specified-head status, the northwestern and southeastern model boundaries that form the long axis of the model grid were configured as no-flow (specified-flux) boundaries. In this case, the flux through these boundaries is assumed to be zero because flow is generally parallel to these boundaries. The base or lower boundary of the model is also assumed to be no-flow, and is arbitrarily set at a depth of 25 feet below the water table based on the estimated thickness of the dissolved BTEX plume. The upper model boundary is defined by the simulated water table surface.

5.3.2 Groundwater Elevation and Gradient

The September 1994 water table elevation map presented on Figure 3.5 was used to define the starting heads input into the Bioplume II model. Water table elevation data from 1994 rather than 1995 were used because more data were available from 1994, allowing greater definition of the groundwater surface topography. However, hydraulic gradients and groundwater flow directions inferred from 1995 data are similar to those inferred from 1994 data. The configuration of groundwater elevation isopleths on Figures 3.5 and 3.6 indicate that groundwater in the study area migrates in a southerly to southwesterly direction toward Red Fox Creek. Lateral hydraulic gradients vary across the study area, and ranged in 1994 from nearly 0.005 ft/ft in the vicinity of the fire training area to approximately 0.0008 ft/ft near the RAPCON site. Additional groundwater flow direction and gradient data are presented by EMCON (1994a). These data are generally consistent with the data collected by Parsons ES in September 1994 and July 1995. Therefore, it was assumed that the observed water levels were reasonably representative of steady-state conditions. As described further in Section 5.4.1, the model was calibrated to the observed September 1994 water table.

5.3.3 BTEX Concentrations

Dissolved BTEX enters groundwater in the study area through two on-going processes: 1) contact between groundwater and residual LNAPL at or below the water table, and 2) migration of recharge (precipitation) through soil containing LNAPL above the water table. Partitioning of BTEX from these sources into groundwater was

simulated using BTEX injection wells at Site FT01 and the RAPCON site. The methods used to estimate the leaching potential of residual LNAPL to groundwater are described in Section 5.4.2. The water injection rate for the injection well was set low enough that the hydraulic calibration of the model was not affected.

The total dissolved BTEX concentrations obtained from July 1995 laboratory analytical results for each monitoring well/point location were used for model development. At well nests, the highest BTEX concentration observed at that location was used. Table 4.3 presents dissolved BTEX concentration data for September 1994 and July 1995, and Figures 4.4 and 4.5 show the spatial distributions of dissolved BTEX compounds for 1994 and 1995, respectively. The magnitudes and shapes of the BTEX plumes depicted in these figures are the result of advective-dispersive transport and biodegradation of dissolved BTEX contamination. As described in Section 5.4.2, the simulated BTEX plume was calibrated to resemble the BTEX plume observed in July 1995.

5.3.4 Dissolved Oxygen

As discussed previously, the Bioplume II model assumes an instantaneous reaction between the BTEX plume and the DO plume. The discussion presented in Section 4.5.2.1 suggests that oxygen is a significant electron acceptor in the study area. The total BTEX plume at the site was modeled assuming that DO was the only electron acceptor being utilized at a rate that is instantaneous relative to the advective groundwater flow velocity for the biodegradation of the BTEX compounds. As described in Section 5.3.5, anaerobic biodegradation was accounted for through the use of a first-order decay rate constant.

As described in Section 4.5.2.1, the average background DO concentrations in 1994 and 1995 were 6.8 and 2.8 mg/L, respectively. For model development, initial (pre-contamination) DO concentrations throughout the modeled area were assigned an intermediate value of 4.5 mg/L. This value is probably conservatively low because the saturation concentration of DO in uncontaminated groundwater ranges from 10 to 13 mg/L depending on the salinity of the water [American Water Works Association (AWWA), 1995]. Water input into the model via the upgradient constant-head cells was assigned a DO concentration of 2.5 mg/L, which was similar to the average background DO concentration measured in July 1995.

Due to the shallow water table and the presence of sandy soils with a relatively low natural organic carbon content, it is reasonable to assume that the precipitation that percolates through the vadose zone contains some DO when it reaches the water table. However, in areas where the soils are contaminated with petroleum, the recharge water may be substantially oxygen-depleted before reaching the water table due to an abundance of oxygen-consuming microbial activity occurring in the contaminated soils. Assuming that the average temperature of precipitation falling on the site is 1°C (34°F), the precipitation would have a DO concentration of approximately 10 to 13 mg/L. Some percentage of this DO is most likely consumed as the water percolates through the vadose zone as a result of microbial processes that utilize naturally occurring organic carbon in the soil. DO was not added to the recharge water in this model because the aerobic

degradation of dissolved BTEX caused by infiltration of oxygenated precipitation within the plume area is at least partially accounted for in the first-order decay constant used in the model (see Section 5.3.5).

5.3.5 Anaerobic Degradation Rates

Available data strongly suggest that anaerobic degradation is occurring in the vicinity of Fire Training Area 1 and the RAPCON Site (Table 4.8). Anaerobic degradation must therefore be simulated with Bioplume II to make solute transport predictions that are meaningful. The Bioplume II model simulates anaerobic biodegradation by assuming that such degradation follows first-order kinetics. As with a large number of biological processes, anaerobic biodegradation can generally be described using a first-order rate constant and the equation:

$$\frac{C}{C_0} = e^{-kt}$$

where: C = Contaminant Concentration at Time t,

C_0 = Initial Contaminant Concentration,

k = Anaerobic Decay Coefficient (anaerobic rate constant), and

t = time.

Two methods of calculating the biodegradation rate constant are currently available to quantify rates of biodegradation at the field scale and are applicable for use with available site data. The first method involves the use of biologically recalcitrant compounds found in the dissolved BTEX plume that can be used as conservative tracers. The second method, proposed by Buscheck and Alcantar (1995), involves interpretation of a steady-state contaminant plume configuration and is based on the one-dimensional, steady-state analytical solution to the advection-dispersion equation presented by Bear (1979). These two methods are each described in more detail in the following paragraphs.

5.3.5.1 Conservative Tracer Method

In order to calculate anaerobic rate constants, the apparent degradation rate must be normalized for the effects of dilution caused by advective/dispersive processes and groundwater recharge. This can be accomplished by normalizing the concentration of each contaminant to the concentration of a component of jet fuel (a tracer) that has sorptive properties similar or greater than those of BTEX, but that is fairly recalcitrant to biological degradation. Observed concentration data can be normalized to TMB compounds (1,3,5-TMB, 1,2,4-TMB, and 1,2,3-TMB) or TEMB compounds (1,2,3,4-TEMB, 1,2,4,5-TEMB, and 1,2,3,5-TEMB). The TMB and TEMB compounds can serve as good tracers because they can be relatively recalcitrant to biodegradation under anaerobic conditions (Cozzarelli *et al.*, 1990 and 1994), and because the sorbtive potentials of TMB and TEMB compounds exceed those of BTEX, which adds a level of conservativeness to the estimate of the anaerobic rate constant. In summary, these

compounds are assumed to respond similarly to the processes of advection and dispersion, and conservatively with respect to sorption. Furthermore, these compounds are not assumed to experience a reduction in concentration due to biodegradation. However, the degree of biological recalcitrance of these tracer compounds is site-specific, and their use as conservative tracers must be evaluated on a case-by-case basis.

The corrected concentration of a compound is the concentration of the compound that would be expected at one point following an interval of time and after correcting for the effects of dispersion, dilution, and sorption between points A and B. One relationship that can be used to calculate the corrected contaminant concentration is:

$$C_{A,Corr} = C_B(TMB_A/TMB_B)$$

Where: $C_{A,Corr}$ = Corrected concentration of contaminant at Point A

C_B = Measured concentration of contaminant at Point B

TMB_A = Measured TMB concentration at Point A, and

TMB_B = Measured TMB concentration at Point B.

A log-linear plot of the corrected contaminant concentrations versus time can be used to determine whether the data set can be described using a first-order exponential equation [i.e., the coefficient of determination (r^2) is greater than approximately 0.9]. When this occurs, the exponential slope can be used as the anaerobic biodegradation rate constant.

An average biodegradation rate constant for BTEX decay at the study area was determined from September 1994 and July 1995 BTEX, TMB, and TEMB data for groundwater (Tables 4.3 and 4.4). The TMB- and TEMB-corrected total BTEX concentrations represent the theoretical BTEX concentration at a point if biodegradation were the only process affecting BTEX concentrations. Biodegradation estimates (Appendix D) predict TMB-corrected biodegradation rate constants for BTEX ranging from 0.004 to 0.008 day^{-1}. The r^2 values range between 0.91 and 0.99, which suggests that the TMB-corrected total BTEX concentrations are well described by a first-order relationship. The anaerobic rate constants calculated using TEMB data exhibited the same range (0.004 to 0.008 day^{-1}), with r^2 values of 0.94 and 0.99. The lower rate constants (0.004 to 0.005 day^{-1}) may be most appropriate for the study area BTEX plume because the migration pathway used to derive these lower values (wells ESMW-1A, MW-95, and 435) coincides most closely with the estimated plume axis.

5.3.5.2 Method of Buscheck and Alcantar

Buscheck and Alcantar (1995) derived a relationship that allows calculation of first-order decay rate constants for steady-state plumes. This method involves coupling the regression of contaminant concentration (plotted on a logarithmic scale) versus distance downgradient (plotted on a linear scale) to an analytical solution for one-dimensional, steady-state, contaminant transport that includes advection, dispersion, sorption, and

biodegradation. For a steady-state plume, the first-order decay rate is given by (Buscheck and Alcantar, 1995):

$$\lambda = \frac{v_c}{4\alpha_x}\left(\left[1 + 2\alpha_x\left(\frac{k}{v_x}\right)\right]^2 - 1\right)$$

Where: λ = first-order decay rate

v_c = retarded contaminant velocity in the x-direction

α_x = dispersivity

k/v_x = slope of line determined from a log-linear plot of contaminant concentration versus distance downgradient along flow path.

The first-order decay rate includes biodegradation resulting from anaerobic and aerobic processes operating along a given path; however, in the absence of DO, the first-order rate is equivalent to the anaerobic decay rate. Appendix D presents first-order rate constant calculations for BTEX using September 1994 and July 1995 groundwater quality data and the method proposed by Buscheck and Alcantar (1995). Calculated rate constants ranged from 0.003 day^{-1} to 0.013 day^{-1}, with closeness-of-fit indicators (r^2 values) ranging from poor (0.62) to excellent (1.00). A rate constant of 0.007, calculated using data from wells ESMW-1A, MW-95, and 435, is judged to be most representative of Site FT01 plume based on the close proximity of these wells to the plume axis. In addition, the loss of BTEX along this flow path has an excellent closeness-of-fit to a first-order biodegradation decay rate because the calculated r^2 was 0.99.

5.3.5.3 Biodegradation Decay Rate Constant Used for Modeling

During the model calibration process, a value of 0.0065 day^{-1} was selected for use as the anaerobic decay coefficient in the model. This value lies within the ranges predicted by both the conservative tracer and the Buscheck and Alcantar methods. Furthermore, the selected value is lower than decay constants frequently reported in the literature (Table 5.1), and therefore is considered to be conservative. For example, Chapelle (1994) reported that at two different sites with anaerobic conditions, the anaerobic decay rate constants both were approximately 0.01 day^{-1}. Wilson *et al.* (1994) report first-order anaerobic biodegradation rates of 0.007 to 0.185 day^{-1}. Stauffer *et al.* (1994) report rate constants of 0.01 and 0.018 day^{-1} for benzene and p-xylene, respectively. The selected anaerobic decay rate also is similar to the rates computed for two sites having similar hydrogeologic conditions at Elmendorf AFB in Anchorage, Alaska (0.004 and 0.01 day^{-1}) (Parsons ES, 1995a and 1995c).

TABLE 5.1
REPRESENTATIVE FIRST-ORDER ANAEROBIC DECAY RATE CONSTANTS
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Reference	Decay Rate (day^{-1})
Chapelle (1994)	0.01[a/]
Buscheck *et al.* (1993)	0.001 to 0.01[a/]
Wiedemeier *et al.* (1995)	0.01 to 0.03[a/]
Wiedemeier *et al.* (1995)	0.03 to 0.04[b/]
Wiedemeier *et al.* (1995)	0.02 to 0.04[c/]
Wiedemeier *et al.* (1995)	0.01 to 0.03[d/]
Wiedemeier *et al.* (1995)	0.006 to 0.03[e/]
Stauffer *et al.* (1994)	0.01[b/] to 0.02[e/]
MacIntyre *et al.* (1993)	0.01 to 0.02[e/]
MacIntyre *et al.* (1993)	0.007 to 0.012[b/]
MacIntyre *et al.* (1993)	0.006 to 0.012[f/]
Barker *et al.* (1987)	0.007[b/]
Kemblowski *et al.* (1987)	0.0085[b/]
Chiang *et al.* (1989)	0.095[b/]
Wilson *et al.* (1990)	0.007 to 0.024[b/]
Howard *et al.* (1991)	0.009 to 0.069[b/]

a/ For total BTEX.
b/ For benzene.
c/ For toluene.
d/ For ethylbenzene.
e/ For xylene.
f/ For naphthalene.

5.4 MODEL CALIBRATION

Model calibration is an important component in the development of any numerical groundwater model. Calibration of the flow model demonstrates that the model is capable of matching hydraulic conditions observed at the site; calibration of a contaminant transport model superimposed upon the calibrated flow model helps verify that contaminant loading and transport conditions are being appropriately simulated. The numerical flow model presented herein was calibrated by altering transmissivity, recharge, and constant-head elevations in a trial-and-error fashion until simulated heads approximated observed field values within a prescribed accuracy. After calibration of the flow model, the numerical solute transport model was calibrated by altering contaminant transport parameters and contaminant source term concentrations in a trial-and-error fashion until the simulated BTEX plume approximated observed field values. Table 5.2 lists input parameters used for the modeling effort. Model input and output are included in Appendix E.

5.4.1 Water Table Calibration

The shallow water table across the study area was assumed to be influenced by continuous recharge and discharge at the constant-head cells established at the upgradient and downgradient model boundaries. In addition, it was assumed that precipitation recharge entered the subsurface across the site, which is almost completely unpaved. As stated in Section 3.1.3, the mean annual precipitation at KSA is approximately 20 inches. The recharge rate for the calibrated groundwater flow model varied from 2 inches per year beneath the surface mound located approximately 200 feet south of the fire training area to 7 inches per year near Red Fox Creek where the water table is relatively shallow.

Hydraulic conductivity is an important aquifer characteristic that represents the ability of the water-bearing strata to transmit groundwater. Transmissivity is the product of the hydraulic conductivity and the thickness of the aquifer. An accurate estimate of hydraulic conductivity is important to help quantify advective groundwater flow velocities and to define the flushing potential of the aquifer and the quantity of electron-acceptor-charged groundwater that is entering the site from upgradient locations. According to Rifai *et al.* (1988), the Bioplume II model is particularly sensitive to variations in hydraulic conductivity. Lower values of hydraulic conductivity result in a slower-moving plume with a relatively small areal extent and higher average BTEX concentrations. Higher values of hydraulic conductivity result in a faster-moving plume that is spread over a larger area and contains lower average BTEX concentrations.

Estimates of the dissolved BTEX plume thickness, geologic data, and water level measurements were used in conjunction with the hydraulic conductivity values derived from slug tests to estimate an initial uniform transmissivity for the contaminated portion of the saturated zone across the entire model domain. As stated in Section 3.4.2.2, hydraulic conductivities derived from slug tests performed in the shallow sandy aquifer in the study area averaged 59 ft/day. Assuming an average plume thickness of 25 feet, the average transmissivity of the contaminated portion of the saturated zone was initially estimated to be 1,475 square feet per day (ft^2/day). To better match heads in the model to observed values, the initial uniform transmissivity was progressively varied in blocks and

TABLE 5.2
BIOPLUME II MODEL INPUT PARAMETERS
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

		Model Runs				
Parameter	Description	Calibrated Model Setup	FT01A	FT01B	FT01C	FT01D
NTIM	Maximum number of time steps in a pumping period	1	1	1	1	1-12[a/]
NPMP	Number of Pumping Periods	1	40	34	34	40
NX	Number of nodes in the X direction	24	24	24	24	24
NY	Number of nodes in the Y direction	40	40	40	40	40
NPMAX	Maximum number of Particles NPMAX=(NX-2)(NY-2)(NPTPND) + (Ns[b/])(NPTPND) + 250	4,850	4,850	4,850	4,850	8,035
NPNT	Time step interval for printing data	1	1	1	1	1
NITP	Number of iteration parameters	7	7	7	7	7
NUMOBS	Number of observation points	0	0	0	0	0
ITMAX	Maximum allowable number of iterations in ADIP [c/]	200	200	200	200	250
NREC	Number of pumping or injection wells	4	4	4	4	4
NPTPND	Initial number of particles per node	9	9	9	9	9
NCODES	Number of node identification codes	2	2	2	2	2
NPNTMV	Particle movement interval (IMOV)	0	0	0	0	0
NPNTVL	Option for printing computed velocities	1	1	1	1	1
NPNTD	Option to print computed dispersion equation coefficients	0	0	0	0	0
NPDELC	Option to print computed changes in concentration	0	0	0	0	0
NPNCHV	Option to punch velocity data	0	0	0	0	0
NREACT	Option for biodegradation, retardation and decay	1	1	1	1	1
PINT	Pumping period (years)	1-12[d/]	1-12[d/]	1-12[d/]	1-12[d/]	1-12[d/]
TOL	Convergence criteria in ADIP	0.001	0.001	0.001	0.001	0.001
POROS	Effective porosity	0.25	0.25	0.25	0.25	0.25
BETA	Characteristic length (long. dispersivity; feet)	35	35	35	35	35

TABLE 5.2 (Continued)
BIOPLUME II MODEL INPUT PARAMETERS
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

		Model Runs				
Parameter	Description	Calibrated Model Setup	FT01A	FT01B	FT01C	FT01D
S	Storage Coefficient	0 (Steady-State)	0	0	0	0
TIMX	Time increment multiplier for transient flow	-	-	-	-	-
TINIT	Size of initial time step (seconds)	-	-	-	-	-
XDEL	Width of finite difference cell in the x direction (feet)	40	40	40	40	40
YDEL	Width of finite difference cell in the y direction (feet)	60	60	60	60	60
DLTRAT	Ratio of transverse to longitudinal dispersivity	0.05	0.05	0.05	0.05	0.05
CELDIS	Maximum cell distance per particle move	0.5	0.5	0.5	0.5	0.5
ANFCTR	Ratio of Tyy to Txx (1 = isotropic)	1.0	1.0	1.0	1.0	1.0
DK	Distribution coefficient	0.62	0.62	0.62	0.62	0.62
RHOB	Bulk density of the solid (grams/cubic centimeter)	1.6	1.6	1.6	1.6	1.6
THALF	Half-life of the solute	-	-	-	-	-
DEC1	Anaerobic decay coefficient (day^{-1})	0.0065	0.0065	0.0065	0.0065	0.0065
DEC2	Reaeration coefficient (day^{-1})	0	0	0	0	0
F	Stoichiometric Ratio of Hydrocarbons to Oxygen	3.1	3.1	3.1	3.1	3.1

a/ First pumping period (12-year duration) was divided into 12 1-year time steps; subsequent pumping periods (1-year duration) each had one time step.

b/ Ns - Number of nodes that represent fluid sources (wells or constant-head cells).

c/ ADIP = Alternating-direction implicit procedure (subroutine for solving groundwater flow equation).

d/ Duration of first pumping period was 12 years (calendar years 1980 - 1992); subsequent pumping periods each lasted 1 year.

rows until the simulated water levels for cells corresponding to the selected well locations closely matched the observed water levels. Figure 5.2 shows the calibrated water table. Calibrated model hydraulic conductivities ranged between 32 and 320 ft/day, with the majority of conductivities ranging between 32 and 200 ft/day. Simulated advective velocities were variable, but generally ranged from 0.3 to 1.1 ft/day (109 to 402 ft/yr) throughout the study area. These velocities compare favorably with the velocity range of 0.2 to 1.1 ft/day (73 to 402 ft/yr) estimated prior to the start of the modeling using available hydraulic conductivity and hydraulic gradient data (see Section 3.3.3.4).

Water level elevation data from 12 monitoring wells were used to compare measured and simulated heads for calibration. The 12 selected locations were MW-92, MW-93, MW-94, MW-95, ESMW-1A, ESMW-2A, ESMW-3A, ESMW-4A, ESMW-5A, ESMW-7A, 462C, and 653. Water level elevation data from wells 435 and 460B were anomalous, and suggested the presence of localized irregularities (mounds and depressions) in the water table (see Section 3.3.2). As stated in Section 5.2, these irregularities were not simulated by the Bioplume model, and therefore, water level data from these wells were not used in the comparison of measured and simulated heads.

The root mean squared (RMS) error is commonly used to express the average difference between simulated and measured heads. RMS error is the average of the squared differences between measured and simulated heads, and can be expressed as:

$$\mathrm{RMS} = \left[\frac{1}{n} \sum_{i=1}^{n} \left(h_m - h_s \right)_i^2 \right]^{0.5}$$

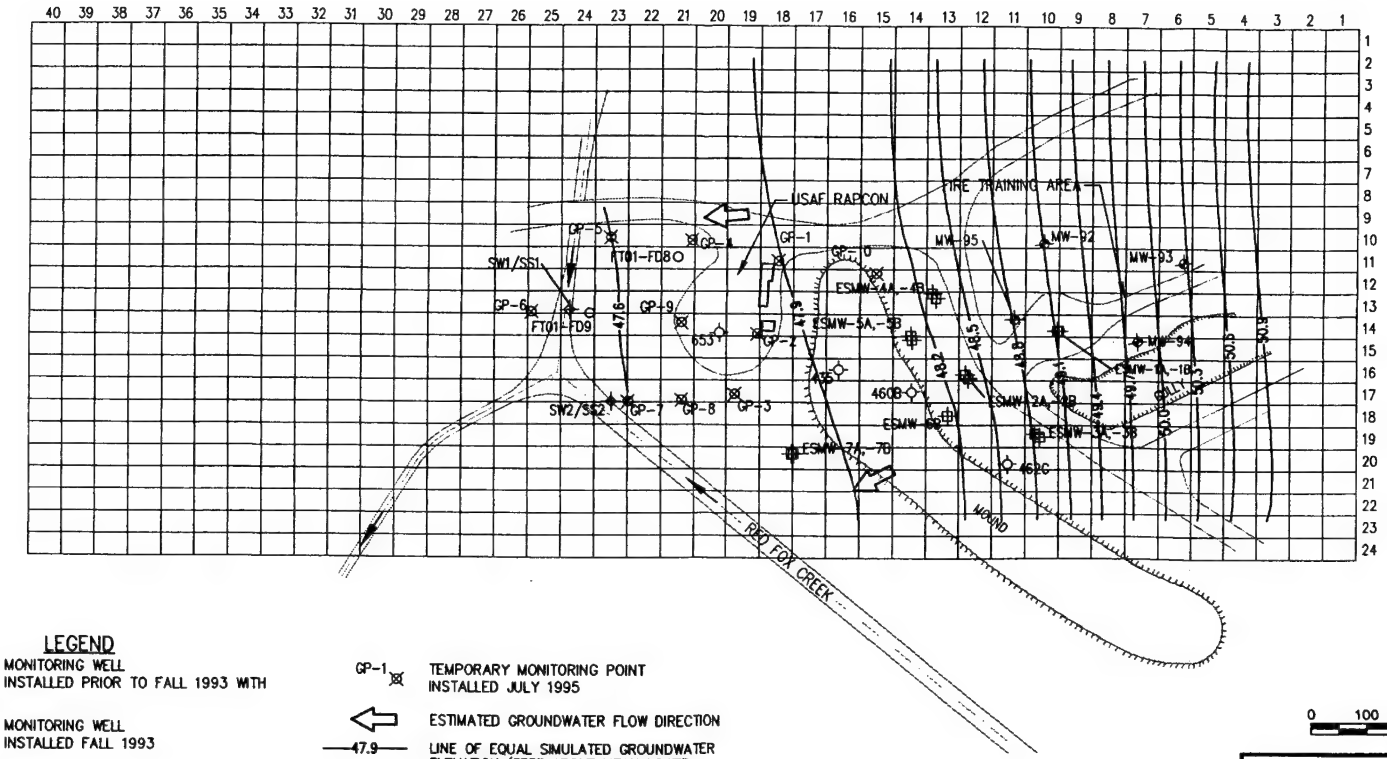
where: n = the number of points where heads are being compared,

h_m = measured head value, and

h_s = simulated head value.

The RMS error between observed and calibrated values at the 12 comparison points was 0.207 foot, which corresponds to a calibration error of 8.6 percent (water levels dropped approximately 2.4 feet over the portion of the model domain containing the monitoring wells/points listed above). RMS error calculations are summarized in Appendix D. The largest variations between observed and simulated values occurred at wells 462C and ESMW-3A, located outside of the BTEX plume near the southeastern model grid boundary. If these wells are not included in the RMS error calculation, the error decreases to 5.8 percent.

In solving the groundwater flow equation, Bioplume II establishes the water table surface and calculates an overall hydraulic balance that accounts for the numerical difference between flux into and out of the system. The hydraulic mass balance for the calibrated model was adequate to accomplish the objectives of this modeling effort, with 98.0 percent of the water flux into and out of the system being numerically accounted for (i.e., a 2.0-percent error).



LEGEND

MW-92 — MONITORING WELL INSTALLED PRIOR TO FALL 1993 WITH

460B — MONITORING WELL INSTALLED FALL 1993

ESMW-5A — MONITORING WELL INSTALLED SEPTEMBER 1994

FT01-FD8 — MONITORING WELL INSTALLED OCTOBER 1994

SW1/SS1 — SURFACE WATER SAMPLING POINT

GP-1 — TEMPORARY MONITORING POINT INSTALLED JULY 1995

ESTIMATED GROUNDWATER FLOW DIRECTION

47.9 — LINE OF EQUAL SIMULATED GROUNDWATER ELEVATION (FEET ABOVE MEAN LOWER LOW WATER)

CONTOUR INTERVAL= 0.3 FOOT

0 100 200 400
FEET

FIGURE 5.2

CALIBRATED GROUNDWATER SURFACE

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

L:\45011\DRAWINGS\FT001\96DN0260, 05/16/96 at 12:01

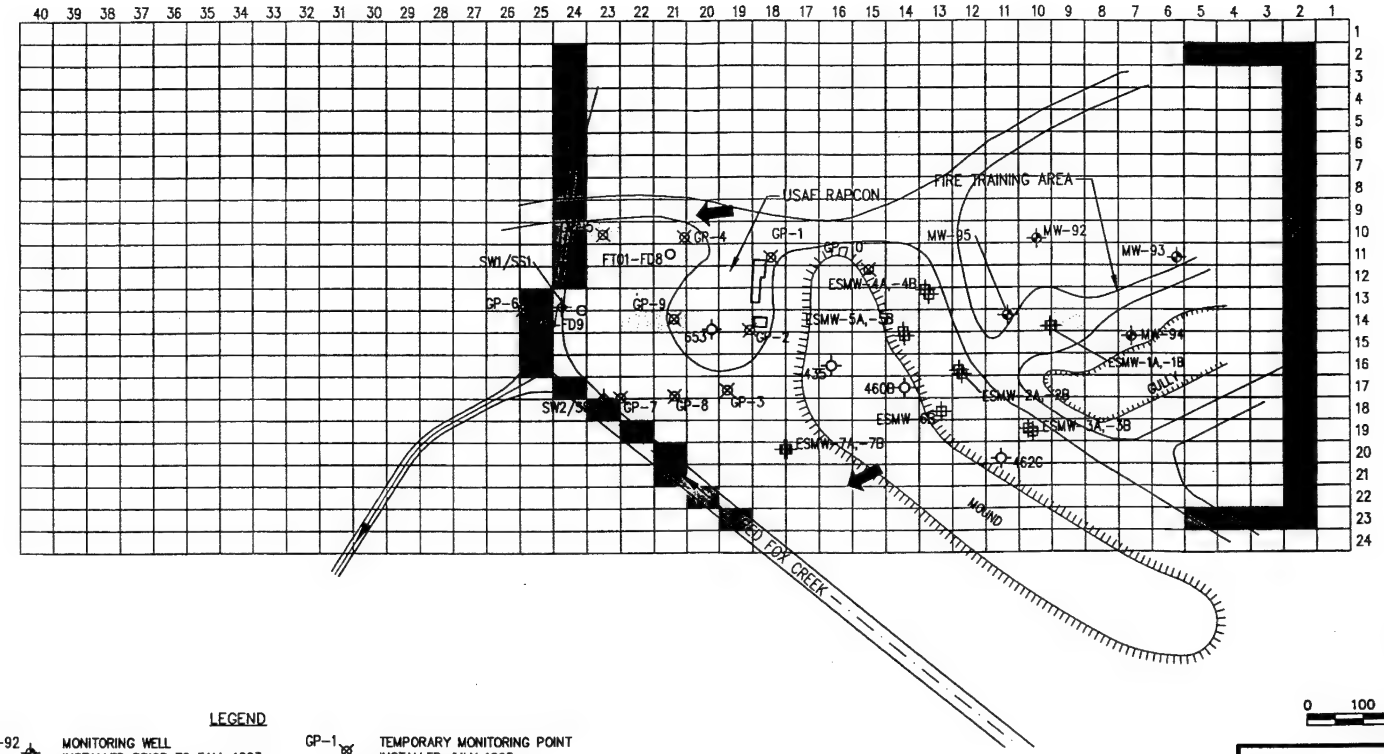
5.4.2 BTEX Plume Calibration

Model input parameters affecting the distribution and concentration of the simulated BTEX plume were modified so that model predictions were similar to total dissolved BTEX concentrations measured in July 1995. To do this, model runs were made using the calibrated steady-state hydraulic parameters coupled with the introduction of contaminants.

Calibration of the fate and transport portion of a Bioplume II model generally requires that the contaminant distribution be known for two different times. Observed July 1995 conditions and assumed 1980 conditions were used for model calibration. Groundwater was assumed to be clean in 1980, prior to initiation of fire training activities. After becoming operational in 1980, FT01 was used steadily until training activities ceased in 1992. For calibration purposes, it was assumed that if all pertinent historical data were known, then an average BTEX source term concentration could be approximated for the period from 1980 to 1992. After 1992, it is reasonable to assume that the contamination source (residual and mobile LNAPL in the subsurface) began to decrease in strength due to the effects of leaching and weathering. The former fire training pit at FT01 was excavated in 1995, and the majority of contaminated soils were removed. To simulate this history, the Bioplume II model was run for 12 years (1980 to 1992) with a constant BTEX source term introducing BTEX into the model at a constant rate. Beginning in simulation year 13 and continuing to simulation year 15 (calendar years 1993 to 1995), the source term was weathered at a geometric rate of 8 percent per year (injected BTEX concentrations were decreased by 8 percent from the concentration used for the previous year to account for natural weathering of fuel residuals). Calibration was achieved by varying BTEX source term concentrations and contaminant transport parameters in the model in a trial and error fashion until a reasonable simulation of the 1995 BTEX plume was achieved. The 8-percent-per-year weathering rate is identical to the rate calculated for a site with similar hydrogeologic and climatic conditions at Elmendorf AFB in Anchorage, Alaska (Parsons ES, 1995c).

The history of the RAPCON site is not well documented. The source of contamination at this site is unclear, and the date(s) of contaminant introduction into the subsurface are not known. Therefore, similar to the Site FT01 plume, the RAPCON plume was calibrated by assuming that contamination was introduced at this site in 1980. The BTEX source term was held constant from 1980 to 1995, and was varied in magnitude until a reasonable match to 1995 observed conditions was obtained.

The partitioning of BTEX compounds from residual LNAPL into the groundwater was simulated by adding injection wells to four cells in the model grid. While the term "injection well" suggests that contaminants are being introduced at a point, Bioplume II assumes that contamination introduced at a well instantly equilibrates throughout the entire cell in which the well is located. The locations of the simulated injection wells are shown on Figure 5.3. Locations of simulated injection wells were based on the known location of the former fire training pit, soil quality data obtained during this study and previous investigations (EMCON, 1994a and 1996a), and the observed distribution of dissolved BTEX in groundwater. The injected BTEX concentrations were proportional to the groundwater BTEX concentrations measured in July 1995, with the maximum



LEGEND

- MW-92 — MONITORING WELL INSTALLED PRIOR TO FALL 1993
- 460B — MONITORING WELL INSTALLED FALL 1993
- ESMW-5A — MONITORING WELL INSTALLED SEPTEMBER 1994
- FT01-FD8 — MONITORING WELL INSTALLED OCTOBER 1994
- SW1/SS1 — SURFACE WATER SAMPLING POINT
- GP-1 — TEMPORARY MONITORING POINT INSTALLED JULY 1995
- ESTIMATED GROUNDWATER FLOW DIRECTION
- LOCATION OF SIMULATED BTEX INJECTION WELL
- CONSTANT HEAD CELLS

FIGURE 5.3

LOCATIONS OF SIMULATED INJECTION WELLS

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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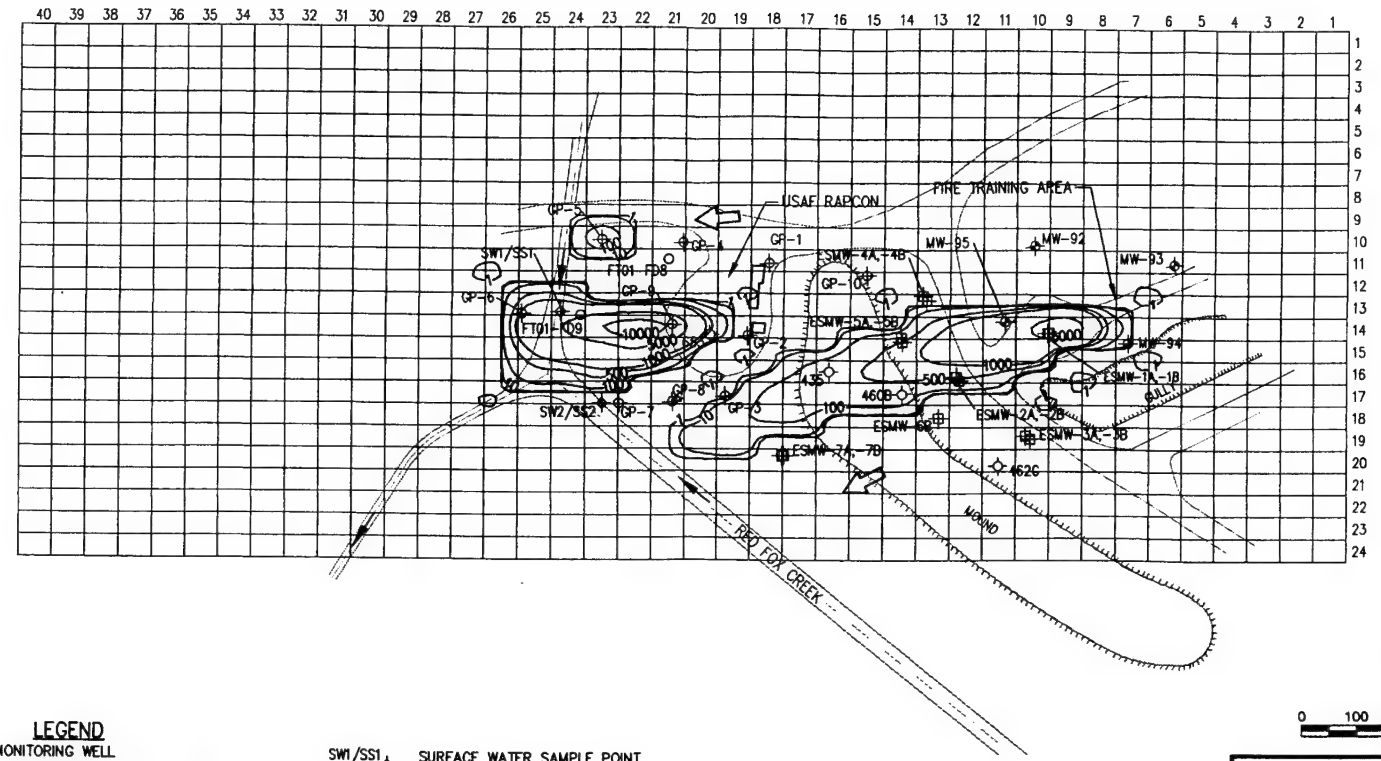
injected BTEX concentration occurring in the vicinity of the highest detected dissolved BTEX concentrations. Because the function of the injections wells was to introduce BTEX into the simulated groundwater system, the injected water was assumed to be oxygen-free. By varying the injection well concentrations, the anaerobic decay coefficient, the coefficient of retardation, dispersivity, and the concentration of DO introduced into the model via the upgradient constant-head cells, the BTEX plume was calibrated reasonably well to the existing plume in terms of plume extent and the magnitude and distribution of BTEX concentrations in the plume area. The injection rate for each well was set at $1x10^{-5}$ cubic foot per second (ft^3/sec), a value low enough that the flow calibration and water balance were not affected.

The calibrated BTEX plumes calculated by the model (Figure 5.4) are similar, but not identical, to the observed 1995 BTEX plumes (Figure 4.5). The primary difference between the simulated and measured plumes emanating from Site FT01 is the BTEX mass in the downgradient portion of the plume. The simulated plume overpredicts the BTEX concentration at the location of downgradient well 435. This well had 81 µg/L BTEX in July 1995, and the simulated BTEX concentration at this location is 296 µg/L. The plume could have been shortened by increasing the anaerobic decay coefficient or the retardation coefficient, but in order to make conservative predictions regarding the impact of the plume on surface water in the creek, this was not done. The maximum simulated BTEX concentration in the Site FT01 source area was 8,415 µg/L, which is similar to the 1995 measured value of 8,620 µg/L.

The simulated BTEX concentration at monitoring point GP-9, which is in or near the probable source area for the RAPCON plume, is 9,822 µg/L. The 1995 measured BTEX concentration in this monitoring point was 9,225 µg/L. The similarity between the measured and simulated BTEX concentrations in the vicinity of well FT01-FD9 (3,806 µg/L and 3,403 µg/L, respectively) indicate that the model is adequately simulating migration of dissolved BTEX from the RAPCON source area to the creek.

Another difference between the simulated and observed BTEX plumes at Site FT01 and the RAPCON site relates to the measured presence of low BTEX concentrations at outlying wells/points MW-92, MW-93, GP-4, and FT01-FD8. The BTEX detected at monitoring point GP-4 and monitoring well FT01-FD8 may indicate the presence of a secondary, relatively minor BTEX source northwest of the main RAPCON plume. These low detections (maximum of 10.1 µg/L in well MW-93) were not reproduced by the model. Furthermore, lateral dispersivity could be more significant in this area because of very low groundwater gradients or seasonal fluctuations in the direction of groundwater flow because of the losing/gaining characteristics of Red Fox Creek. The low BTEX concentrations are considered to be insignificant relative to the much higher BTEX concentrations present in the primary fire training area and RAPCON plumes.

One final distinction between the simulated and measured BTEX plumes is that in Figures 4.4 and 4.5 the Site FT01 and the RAPCON site plumes are portrayed as intermingling to a degree. This interpretation is neither confirmed nor disproved by field data, and is therefore subject to interpretation. The simulated BTEX plumes are separated.



LEGEND

- MW-92 — MONITORING WELL INSTALLED PRIOR TO FALL 1993
- 460B — MONITORING WELL INSTALLED FALL 1993
- ESMW-5A — MONITORING WELL INSTALLED SEPTEMBER 1994
- FT01-FD8 — MONITORING WELL INSTALLED OCTOBER 1994
- SW1/SS1 — SURFACE WATER SAMPLE POINT
- GP-1 — TEMPORARY MONITORING POINT INSTALLED JULY 1995
- ESTIMATED GROUNDWATER FLOW DIRECTION
- —100— LINE OF EQUAL SIMULATED BTEX CONCENTRATION (µg/L) CONTOUR INTERVAL = VARIABLE

FIGURE 5.4

CALIBRATED BTEX PLUME

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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As noted previously, the transport parameters varied during plume calibration were dispersivity, the anaerobic decay rate constant, and the coefficient of retardation. In addition, the BTEX source term injection concentrations and DO input concentrations were varied. Because the original estimates for the parameters resulted in a calculated BTEX plume that did not reasonably reproduce the original plume, these parameters generally were varied with the intent of limiting plume migration to the observed extents. Each of these parameters are discussed in the following paragraphs.

5.4.2.1 Dispersivity

Much controversy surrounds the concepts of dispersion and dispersivity. Longitudinal dispersivity was originally estimated as 50 feet, using one-tenth the distance between the Site FT01 source area and the estimated downgradient plume boundary (Figure 4.5). Transverse dispersivity values generally are estimated as one-tenth (0.1) of the longitudinal dispersivity values (Domenico and Schwartz, 1990). However, because the 1995 Site FT01 and RAPCON site plumes were relatively narrow, the ratio of transverse to longitudinal dispersivity was reduced to 0.05. During plume calibration, the longitudinal dispersivity was reduced to 35 feet to better simulate the narrow, linear shape of the BTEX plume. This is the value used to produce the calibrated plumes depicted in Figure 5.4. Increasing the dispersivity above this value caused the model to overpredict BTEX concentrations at downgradient well 435 to an unreasonable degree.

5.4.2.2 Anaerobic Decay Rate Constant

As discussed in Section 5.3.5, the anaerobic decay rate constant was estimated to range from 0.003 day^{-1} to 0.013 day^{-1}. This parameter was varied during plume calibration, and the calibrated model used a value of 0.0065 day^{-1}. Use of this value yielded a good match between simulated and measured BTEX concentrations. However, the value appears to be reasonably conservative because the model-simulated BTEX concentration at downgradient well 435 (296 µg/L) is greater than the concentration measured at this well in 1995 (81 µg/L). Therefore, the model appears to be overpredicting plume migration in the downgradient direction. Furthermore, use of this intermediate value allowed the maximum simulated BTEX concentration in the source area to resemble the maximum measured concentration in monitoring well ESMW-5A. The value of 0.0065 day^{-1} used in the calibrated model is believed to be reasonably conservative.

5.4.2.3 Coefficient of Retardation

Retardation of the BTEX compounds relative to the advective velocity of the groundwater occurs when BTEX molecules are sorbed to organic carbon, silt, or clay in the aquifer matrix. Based on measured TOC concentrations near the water table at five locations, an assumed bulk density of 1.6 grams per cubic centimeter (g/cc) (typical for sediments of this type), and published values of the soil sorption coefficient (K_{oc}) for the BTEX compounds (as listed in Wiedemeier *et al.*, 1995), the coefficients of retardation for the BTEX compounds were calculated. The results of these calculations are summarized in Table 5.3. The lower the assumed coefficient of retardation, the faster the BTEX plume will migrate downgradient. Initially, the average retardation coefficient

TABLE 5.3
CALCULATION OF RETARDATION COEFFICIENTS
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Compound	K_{oc} (L/kg [a/])	Maximum Fraction Organic Carbon [b/]	Minimum Fraction Organic Carbon [b/]	Average Fraction Organic Carbon [b/]	Distribution Coefficient K_d (L/kg) Maximum [c1/]	Minimum [c2/]	Average [c3/]	Bulk Density (kg/L) [d/]	Effective Porosity [e/]	Coefficient of Retardation Maximum	Minimum	Average
Benzene	79	0.00036	0.00015	0.00019	0.028	0.012	0.015	1.60	0.25	1.18	1.08	1.10
Toluene	190	0.00036	0.00015	0.00019	0.068	0.029	0.036	1.60	0.25	1.44	1.18	1.23
Ethylbenzene	468	0.00036	0.00015	0.00019	0.168	0.070	0.089	1.60	0.25	2.08	1.45	1.57
m-xylene	405	0.00036	0.00015	0.00019	0.146	0.061	0.077	1.60	0.25	1.93	1.39	1.49
o-xylene	422	0.00036	0.00015	0.00019	0.152	0.063	0.080	1.60	0.25	1.97	1.41	1.51
p-xylene	357	0.00036	0.00015	0.00019	0.129	0.054	0.068	1.60	0.25	1.82	1.34	1.43
Total BTEX	283	0.00036	0.00015	0.00019	0.102	0.042	0.054	1.60	0.25	1.65	1.27	1.34

NOTES:

[a/] From technical protocol (Wiedemeier *et al.* , 1995)

[b/] From laboratory analyses of site soil samples

[c1/] K_d = Maximum Fraction Organic Carbon x K_{oc}

[c2/] K_d = Minimum Fraction Organic Carbon x K_{oc}

[c3/] K_d = Average Fraction Organic Carbon x K_{oc}

[d/] From laboratory analyses of moisture content, and assumed porosity and specific gravity.

[e/] Literature value.

Note: K_{oc} for BTEX is the average of individual values for benzene, toluene, ethylbenzene, and total xylenes.

calculated for benzene (1.10), which is the least retarded of the BTEX compounds, was used in the model. During the plume calibration, this value was varied, and a value of 1.40 was used in the calibrated model. This value is similar to the average calculated retardation coefficient for the family of BTEX compounds of 1.34 (Table 5.3). The measured benzene concentrations at wells ESMW-1A, MW-95, and 435 were approximately 9 percent, 17 percent, and 35 percent of the total BTEX concentrations, respectively. Therefore, use of a retardation coefficient that is more representative of BTEX than of benzene is reasonable. Similar to the anaerobic decay coefficient described above, use of this value allowed the simulated BTEX concentrations at downgradient monitoring well 435 and in the source area at ESMW-1A to be similar to measured concentrations. Raising the retardation coefficient further would have caused the simulated and measured BTEX concentrations at well 435 to be more comparable; however, the lower retardation coefficient was selected to make the model more conservative.

5.4.2.4 Source Injection Concentration

Four injection wells were used to simulate the partitioning of BTEX from residual LNAPL in the vicinity of the plume (Figure 5.3). The water injection rate ($1x10^{-5}$ ft^3/sec) was sufficiently low that the calibrated flow system was not altered. The injected BTEX concentrations were varied until the calibrated plume matched measured conditions reasonably well. The first two injection wells were located in the immediate vicinities of monitoring well ESMW-1A and monitoring point GP-9, where the highest dissolved BTEX concentrations were detected. During the calibration process, it became necessary to add a second injection well in the RAPCON plume that was closer to the creek [grid cell (14,22)] in order to simulate the measured BTEX concentration at well FT01-FD9. The fourth injection well is located at monitoring point GP-5 [grid cell (10,23)] to simulate the relatively low dissolved BTEX concentration detected at this location.

5.4.2.5 DO Concentrations at Upgradient Model Boundary

The anaerobic decay rate constant calculated using the method of Buscheck and Alcantar (1995) (Section 5.3.5.2) also accounts for at least a portion of the aerobic decay of dissolved BTEX occurring in the aquifer. Therefore, water input into the model via the upgradient constant-head cells was initially assigned a DO content of zero. However, this resulted in a wider plume that incorporated bounding wells at which BTEX was not detected in 1995, despite corresponding increases in the retardation coefficient and anaerobic decay rate constant. Therefore, a DO concentration of 2.5 mg/L at the upgradient flow boundary was assigned to the water input into the calibrated model to narrow the plume and better reproduce the 1995 measured plume.

5.5 SENSITIVITY ANALYSIS

The purpose of the sensitivity analysis is to determine the effect of varying model input parameters on model output. According to Rifai *et al.* (1988), the Bioplume II model is most sensitive to changes in the coefficient of reaeration, the anaerobic decay rate constant, and the hydraulic conductivity of the media, and is less sensitive to changes in the retardation factor, porosity, and dispersivity. The sensitivity analysis was

conducted by varying transmissivity, the coefficient of retardation, the anaerobic decay rate constant, dispersivity, and BTEX injection concentrations. The coefficient of reaeration was not included in the sensitivity analyses because it was set to zero in the model. Use of a non-zero reaeration coefficient would make the model less conservative.

To perform the sensitivity analyses, the calibrated model was adjusted by systematically changing the aforementioned parameters individually, and then comparing the new simulations to the results of the original calibrated model. The models were run for a 15-year period, just as the original was, so that the independent effect of each variable could be assessed. Ten sensitivity runs of the calibrated model were made, with the following variations:

1. Transmissivity uniformly increased by a factor of 5;
2. Transmissivity uniformly decreased by a factor of 5;
3. Coefficient of retardation increased by a factor of 2;
4. Coefficient of retardation decreased from 1.4 to 1.0 (no retardation);
5. Dispersivity increased by a factor of 5;
6. Dispersivity decreased by a factor of 5;
7. Anaerobic decay rate constant increased by a factor of 3;
8. Anaerobic decay rate constant decreased by a factor of 3;
9. Injected BTEX concentrations increased by a factor of 2; and
10. Injected BTEX concentrations decreased by a factor of 2.

The results of the sensitivity analyses are shown in figures discussed in the following subsections. These figures display three-dimensional representations of modeled BTEX concentrations. The vertical axis of each three-dimensional figure represents the BTEX concentration in mg/L. As described in the following paragraphs, the parameter modifications listed above generally resulted in substantial changes in the resulting BTEX plumes, with the dispersivity modifications having the smallest effect.

5.5.1 Sensitivity to Variations in Transmissivity

The effects of varying transmissivity are shown in Figure 5.5. Uniformly increasing the transmissivity by a factor of five increased the lateral dispersal of the plume such that the simulated BTEX concentrations in the vicinity of source area monitoring well ESMW-1A (Site FT01) and monitoring point GP-9 (RAPCON site) were only 1,117 µg/L and 4,065 µg/L, respectively, compared to the calibrated concentrations of 8,415 µg/L and 9,822 µg/L. The measured BTEX concentrations in ESMW-1A and GP-9 (July 1995) were 8,615 µg/L and 9,230 µg/L, respectively. The maximum dissolved BTEX concentration in the modeled area simulated by the calibrated model (12,290 µg/L) was

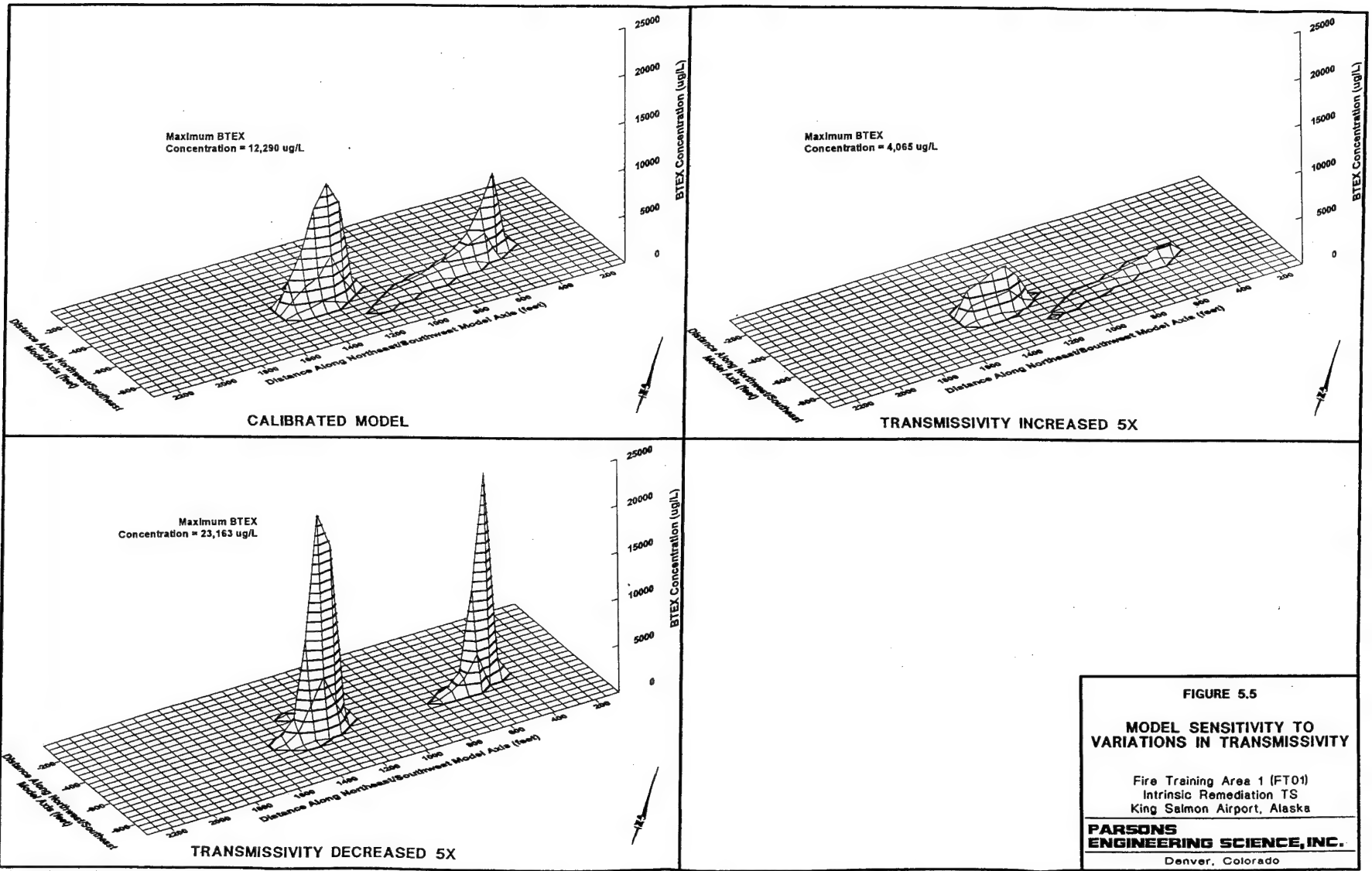

FIGURE 5.5

MODEL SENSITIVITY TO VARIATIONS IN TRANSMISSIVITY

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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located immediately southwest of GP-9 in model grid cell (14,22). Increasing the transmissivity by a factor of five caused the simulated concentration in this cell to decrease to 4,065 µg/L. In addition, the simulated concentration near Red Fox Creek at well FT01-FD9 was only approximately 1,780 µg/L, compared to the calibrated and field-measured concentrations of 3,403 µg/L and 3,806 µg/L, respectively. However, the leading edges of the BTEX plumes did not advance further downgradient than predicted by the calibrated model because both simulated plumes terminate at Red Fox Creek.

In contrast, decreasing the transmissivity by a factor of five slowed overall plume migration, and caused the BTEX mass to be concentrated within a smaller area. As a result, BTEX levels in the vicinities of source area monitoring well ESMW-1A and monitoring point GP-9 increased to 12,240 µg/L and 19,513 µg/L, respectively. Similarly, the simulated maximum BTEX concentration in grid cell (14,22) increased from 12,290 µg/L to 23,163 µg/L. The simulated BTEX plume emanating from the Fire Training Area was also substantially shorter than measured in the field, migrating approximately 250 feet downgradient from source area well ESMW-1A. In July 1995, 81 µg/L BTEX was detected in downgradient well 435, which is located approximately 400 feet from well ESMW-1A.

5.5.2 Sensitivity to Variations in the Coefficient of Retardation

The effects of varying the coefficient of retardation (R) are shown on Figure 5.6. Increasing R causes the contaminant migration velocity to decrease relative to the advective groundwater velocity. Increasing R to 2.8 from the value of 1.4 used in the calibrated model resulted in a Site FT01 plume configuration that was substantially shorter (by approximately 330 feet) than the calibrated plume. The simulated BTEX plume emanating from the fire training area did not extend to downgradient well 435, which had a measured BTEX concentration of 81 µg/L in July 1995. In addition, the faster sweep of electron-acceptor-enriched groundwater through the BTEX plume results in more rapid biodegradation and a corresponding decrease in dissolved BTEX concentrations throughout the plume. The simulated BTEX concentrations at Site FT01 and RAPCON source area monitoring well ESMW-1A and monitoring point GP-9 were 6,349 µg/L and 7,917 µg/L, respectively. These values are substantially less than the calibrated concentrations (July 1995) in these well/point locations of 8,415 µg/L and 9,822 µg/L. The simulated study area maximum BTEX concentration in grid cell (14,22) decreased from 12,290 µg/L in the calibrated model to 9,402 µg/L. The simulated BTEX concentration at downgradient monitoring station FT01-FD9 (RAPCON plume) was approximately 1,200 µg/L, compared to the calibrated concentration of 3,403 µg/L.

Decreasing R to 1.0 (no retardation) produced Site FT01 and RAPCON plumes characterized by substantially elevated BTEX concentrations in their downgradient reaches compared to the measured and calibrated plumes. In this simulation, both contaminants and groundwater migrate at the same rate; therefore, electron-acceptor-enriched groundwater does not sweep through the unretarded BTEX plume. For example, the simulated BTEX concentrations at downgradient monitoring wells 435 (Site FT01) and FT01-FD9 (RAPCON site) were 830 µg/L and 4,484 µg/L, respectively, compared to actual measured concentrations of 81 and 3,806 µg/L and calibrated concentrations of 296 and 3,403 µg/L. A dissolved BTEX concentration in grid cell

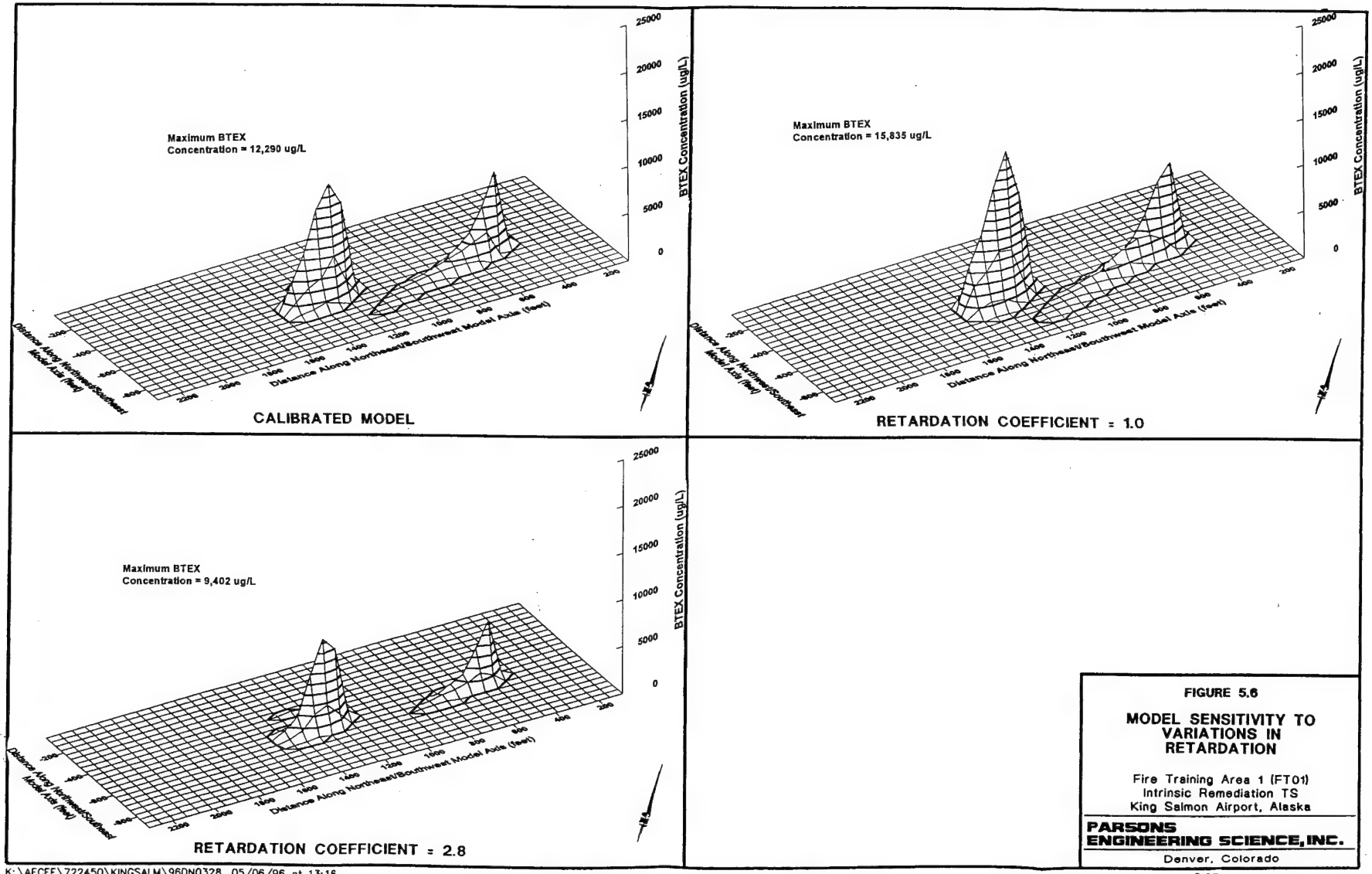

FIGURE 5.6

MODEL SENSITIVITY TO VARIATIONS IN RETARDATION

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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(14,22) of 15,835 µg/L was obtained compared to the calibrated value of 12,290 µg/L. The simulated BTEX concentrations in the fire training pit and RAPCON source areas at monitoring well ESMW-1A and monitoring point GP-9 were 9,259 µg/L and 10,809 µg/L, respectively. These values are similar to but higher than the calibrated concentrations in these well/point locations of 8,415 µg/L and 9,822 µg/L.

5.5.3 Sensitivity to Variations in Dispersivity

The effects of varying dispersivity are illustrated in Figure 5.7. Both longitudinal and transverse dispersivity were varied for this analysis, as the ratio of the two values was kept constant at 0.050. Increasing the dispersivity by a factor of five resulted in relatively low BTEX concentrations in the FT01 and RAPCON source areas. The highest BTEX concentration simulated for the modeled area [grid cell (14,22)] was 9,289 µg/L compared to the calibrated maximum concentration of 12,290 µg/L. The simulated concentrations at source area monitoring well ESMW-1A and monitoring point GP-9 were 4,246 µg/L and 8,017 µg/L, respectively, compared to calibrated concentrations of 8,415 and 9,822 mg/L. A corresponding increase in concentrations upgradient from the RAPCON site source area was also observed, causing the simulated BTEX concentration at upgradient point GP-2 (BTEX less than 4 µg/L in July 1995) to increase from nondetect in the calibrated model to 966 µg/L. In other respects however, the use of a larger dispersivity value did not substantially alter the plume configurations, supporting the observation that the Bioplume II model is less sensitive to variations in dispersivity than to variations in other contaminant transport parameters.

Decreasing the dispersivity by a factor of five produced a plume with areal extents similar to the calibrated and field-measured plumes, but with slightly higher concentrations. For example, the simulated BTEX concentration at fire training area well ESMW-1A was 11,135 µg/L, compared to the measured July 1995 and calibrated model concentrations of 8,615 and 8,415 µg/L, respectively. The simulated study area maximum BTEX concentration in grid cell (14,22) was 15,571 µg/L, compared to the calibrated concentration of 12,290 µg/L.

5.5.4 Sensitivity to Variations in the Anaerobic Decay Rate Constant

Figure 5.8 shows the effects of varying the anaerobic decay rate constant. Changes in this parameter significantly affect model results because the term is exponentiated in the equation expressing the decay rate (see Section 5.3.5). Increasing this parameter by a factor of three results in more rapid degradation of dissolved BTEX. The reduction in contaminant mass is the result of the relatively large increase in the decay rate caused by increasing the rate constant. The resulting simulated BTEX concentrations at source area well ESMW-1A and monitoring point GP-9 were relatively low (5,950 µg/L and 5,596 µg/L, respectively), as was the maximum simulated BTEX concentration for the modeled area [grid cell (14,22)] of 7,314 µg/L. In addition, the simulated FT01 plume is approximately 450 feet shorter than the calibrated plume. The shortened plume does not reach downgradient monitoring well 435, where a BTEX concentration of 81 µg/L was measured in July 1995.

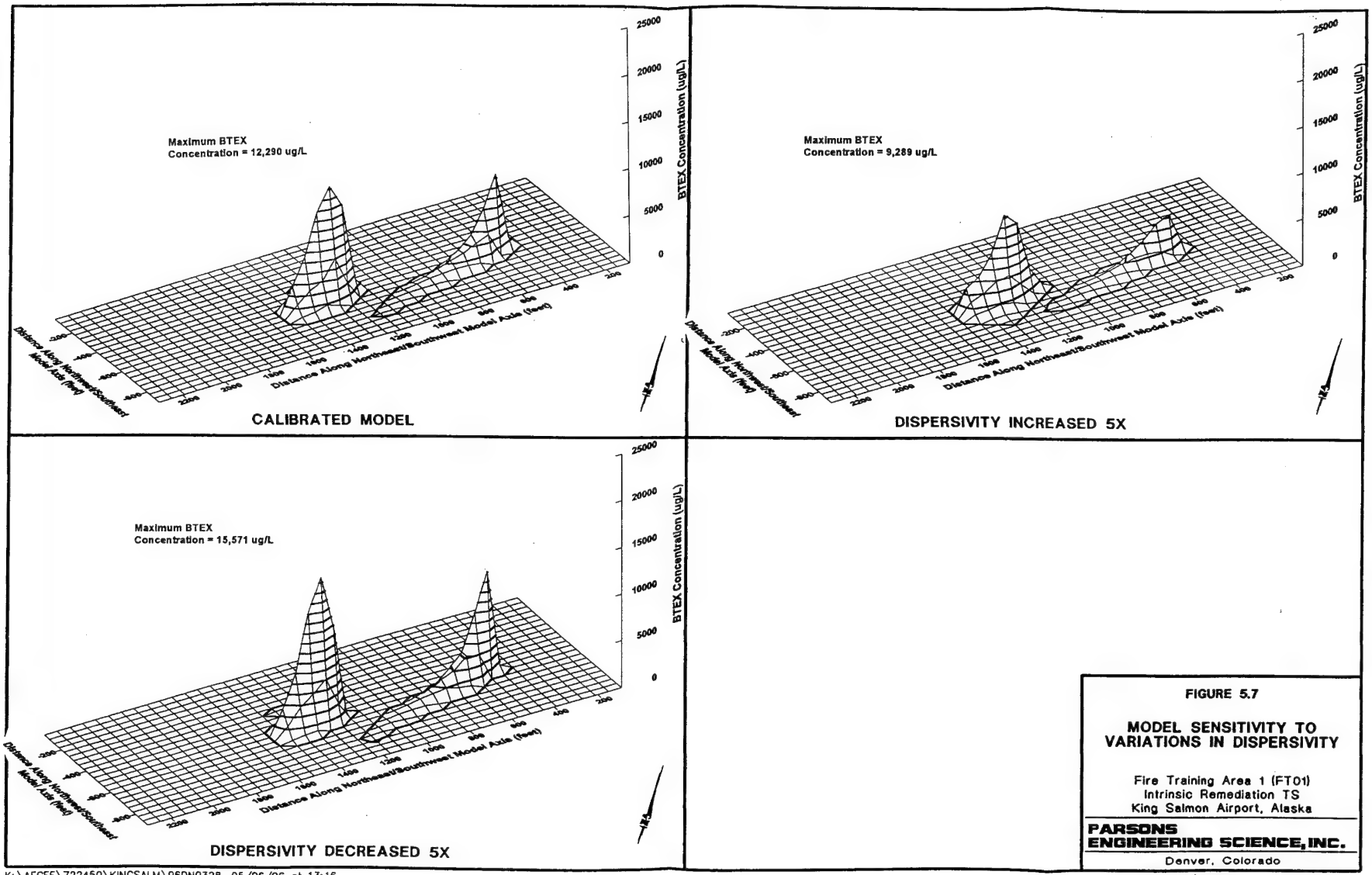

FIGURE 5.7

MODEL SENSITIVITY TO VARIATIONS IN DISPERSIVITY

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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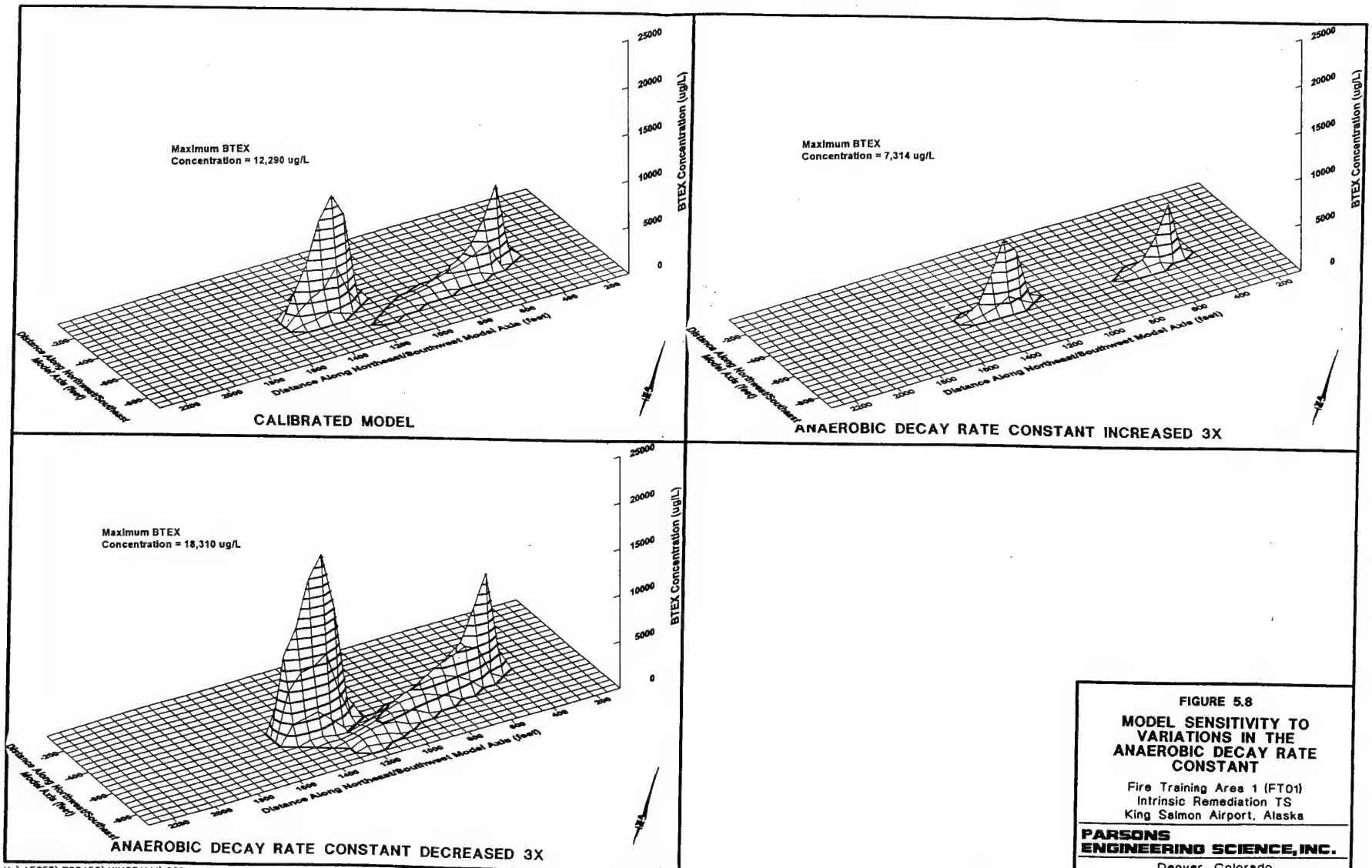

FIGURE 5.8

MODEL SENSITIVITY TO VARIATIONS IN THE ANAEROBIC DECAY RATE CONSTANT

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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Conversely, decreasing the anaerobic decay rate constant by a factor of three decreases the rate of degradation, resulting in an overall increase in simulated source area and downgradient BTEX concentrations to levels that were above observed concentrations. For example, the simulated BTEX concentrations at monitoring wells 435 and FT01-FD9 were approximately 1,900 µg/L and 7,270 µg/L, respectively, compared to calibrated concentrations of 296 and 3,403 µg/L. Simulated concentrations in the source areas also were substantially higher than observed and calibrated concentrations. The simulated BTEX concentration in source cell (14,22) was 18,310 µg/L, compared to a calibrated value of 12,290 µg/L. The resulting plumes were also wider than either the field-measured or calibrated plumes. For example, simulated BTEX concentrations at monitoring points GP-7 and GP-8, which did not contain detectable amounts of BTEX in July 1995, were greater than 100 µg/L.

5.5.5 Sensitivity to Variations in Injected BTEX Concentrations

The injected BTEX concentrations in the initial calibrated model ranged from 35,000 µg/L to 1,220,000 µg/L, with an injection rate of $1x10^{-5}$ ft^3/sec. The results of increasing and decreasing the injected BTEX concentrations by a factor of two are shown on Figure 5.9. Increasing the injected concentrations by a factor of two approximately doubles the simulated source area concentrations at well ESMW-1A (fire training area) and monitoring point GP-9 (RAPCON site) to 18,233 mg/L and 18,650 µg/L, respectively, and generally substantially increases BTEX concentrations throughout the plume over those measured in the field. The overall maximum simulated BTEX concentration for the modeled area [grid cell (14,22)] was 26,539 µg/L, compared to a calibrated maximum of 12,290 µg/L. Simulated concentrations at downgradient wells 435 and FT01-FD9 were 769 µg/L and 6,501 µg/L, respectively, whereas the calibrated concentrations at these wells were 296 and 3,403 µg/L. Decreasing the injected BTEX concentrations by a factor of two causes the overall simulated maximum BTEX concentration in the modeled area to decrease from 12,290 µg/L to 6,450 µg/L, and the calibrated BTEX concentrations at the two source area wells identified above to decline to 4,317 µg/L (ESMW-1A) and 4,435 µg/L (GP-9). Furthermore, the overall size of the FT01 plume is reduced relative to the calibrated model and observed plume dimensions.

5.5.6 Summary of Sensitivity Analysis Results

The results of the sensitivity analysis suggest that the calibrated model depicted in Figures 5.5 through 5.9 is reasonable. Varying the model parameters within the prescribed ranges generally caused the extent and magnitude of the dissolved BTEX plume to differ substantially from measured conditions. The greatest effects were observed when varying the transmissivity (Figure 5.5) and BTEX injection concentrations (Figure 5.9) within reasonable ranges, and the smallest effects were observed when varying the dispersivity (Figure 5.7). The sensitivity analyses did suggest that use of a larger retardation factor and/or anaerobic decay rate constant would improve the calibration of the model by further restricting the downgradient migration of the plume; however, the values used in the calibrated model (which cause the simulated BTEX concentration at downgradient well 435 to exceed the July 1995 measured concentration) were retained to preserve the conservative nature of the model.

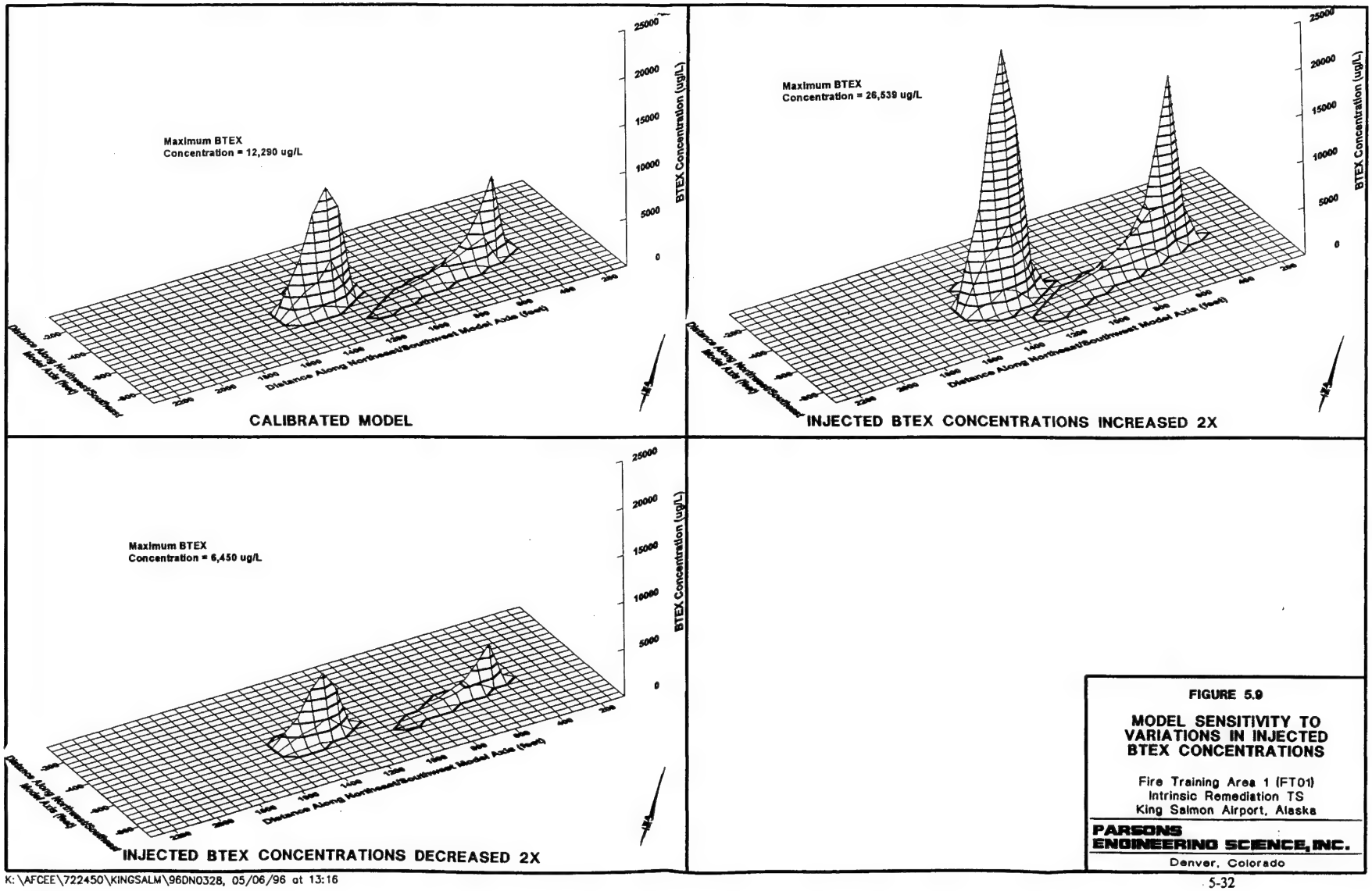

FIGURE 5.9

MODEL SENSITIVITY TO VARIATIONS IN INJECTED BTEX CONCENTRATIONS

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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5.6 MODEL RESULTS

To predict the fate and transport of dissolved BTEX across the study area, four Bioplume II simulations (FT01A, FT01B, FT01C, and FT01D) were run using the calibrated, steady-state groundwater flow system. Complete input and output files are presented in Appendix E. Model results are described in the following sections. Model time for the predictive simulations is described using the term "simulation time," which refers to model time after the initial 15-year calibration period (i.e., simulation time after calendar year 1995).

The first simulation (FT01A) assumed that, after cessation of fire training exercises in 1992, the rates at which the BTEX compounds were introduced into the aquifer at the fire training area through injection wells geometrically decreased by 8 percent per year, as described in Section 5.4.2. BTEX injection concentrations associated with the fire training area plume were decreased in this manner during calendar years 1993, 1994, and 1995. The model incorporates an 80-percent reduction of fire-training-related injection concentrations from 1995 to 1996 to simulate the 1995 excavation of the fire training pit. It was assumed that 20 percent of the residual LNAPL contamination present at the time of excavation was outside of the excavation boundaries, and therefore was not removed. The remaining 20 percent of the simulated BTEX source was then weathered at the 8-percent rate described above beginning in 1997.

Model FT01A assumes that the contamination at the RAPCON site also was introduced during the same year that fire training exercises began (1980), and source concentrations were held constant through calendar year 1995. The BTEX injection concentrations associated with the RAPCON site were reduced by 8 percent per year beginning in calendar year 1996.

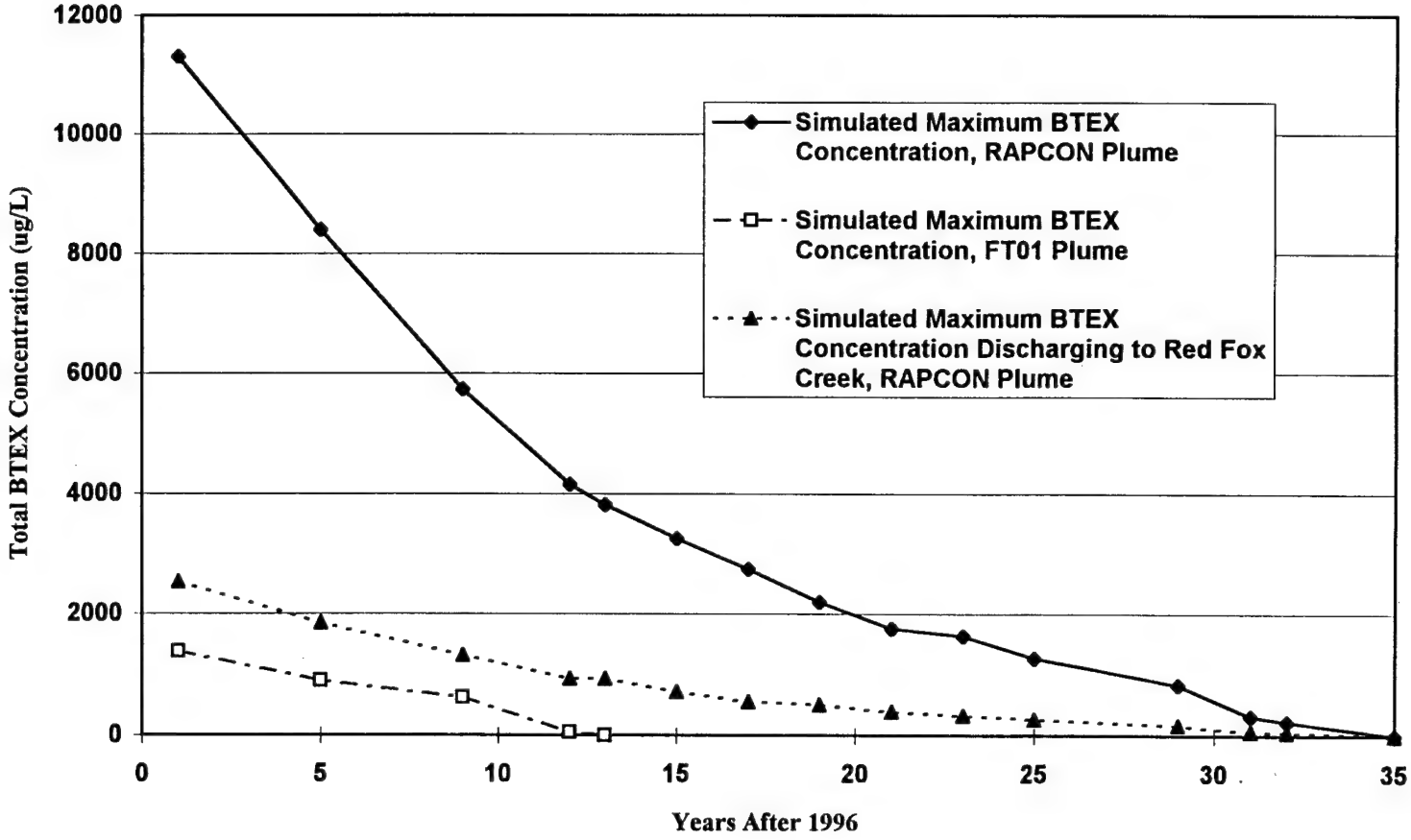
The second simulation (FT01B) is identical to FT01A for the FT01 source area; however, it assumes that 80 percent of the contamination source at the RAPCON site is removed via excavation during calendar year 1997, and the remaining 20 percent is reduced at the weathering rate of 8 percent per year used in model FT01A. The third simulation (FT01C) assumes that, in addition to the excavation of the RAPCON source area simulated in model FT01B, an air sparging curtain is installed near the upgradient bank of Red Fox Creek to prevent BTEX in the RAPCON plume from discharging to the creek. Simulation FT01D assumes that the RAPCON plume migrates beneath Red Fox Creek rather than discharging to the creek, and therefore evaluates the distance the plume would migrate past the creek. In other respects, model FT01D is similar to model FT01A.

5.6.1 Diminishing BTEX Source (Model FT01A)

To predict the fate and transport of dissolved BTEX compounds in the study area, model FT01A was run for a period of 36 years beyond 1995 (to calendar year 2031). This model incorporates the source term reductions described above.

The temporal variations in the maximum dissolved BTEX concentrations in the FT01 and RAPCON plumes are shown on Figure 5.10, and plume isopleth maps for simulation years 5 and 9 (calendar years 2000 and 2004) are shown on Figure 5.11. The model

FIGURE 5.10
SIMULATED TEMPORAL VARIATIONS IN BTEX CONCENTRATIONS
MODEL FT01A
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA



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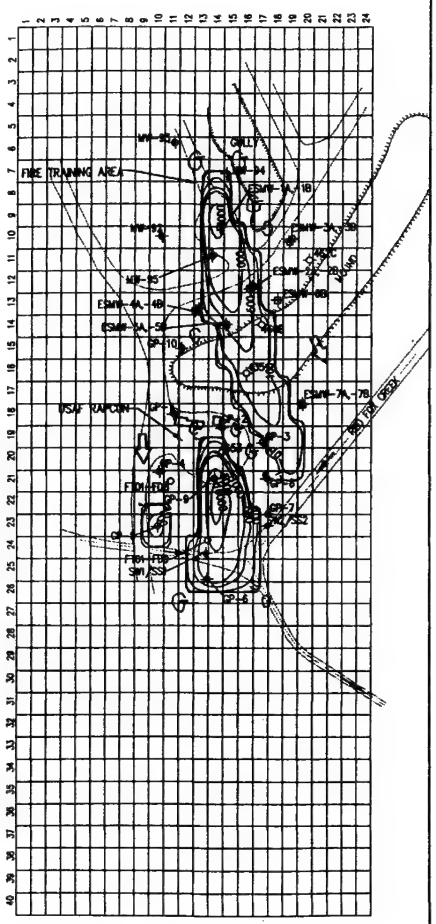
FIRE TRAINING AREA
GULLY
MW-92
MW-24
ESMW-1A-1B
ESMW-3A-3B
MW-95
ESMW-2A-2B
ESMW-6B
ESMW-4A-4B
ESMW-5A-5B
GP-10
ESMW-7A-7B
USAF RAPCON
GP-1
GP-2
GP-3
GP-4
GP-5
GP-6
GP-7
GP-8
GP-9
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SS2
SW2
SW3
SS3
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indicates that, with the majority of the contamination source removed in 1995, the BTEX plume emanating from Site FT01 will rapidly recede from Red Fox Creek and diminish in magnitude and extent. Discharge of the Site FT01 plume to the creek, if it ever occurred, is not predicted to continue beyond 1995; therefore, the plume does not appear to pose a continuing threat to potential receptors exposed to contaminants in the creek. The model predicts that the FT01 plume will disappear following simulation year 12 (calendar year 2007).

As shown on Figures 5.10 and 5.11, model FT01A predicts that the RAPCON plume will be present for a substantially longer period of time than the Site FT01 plume. The model predicts that the RAPCON plume will be completely biodegraded by simulation year 35 (calendar year 2030), and Figure 5.10 indicates that BTEX will discharge to Red Fox Creek for the same time period.

5.6.2 Engineered RAPCON Source Reduction (Model FT01B)

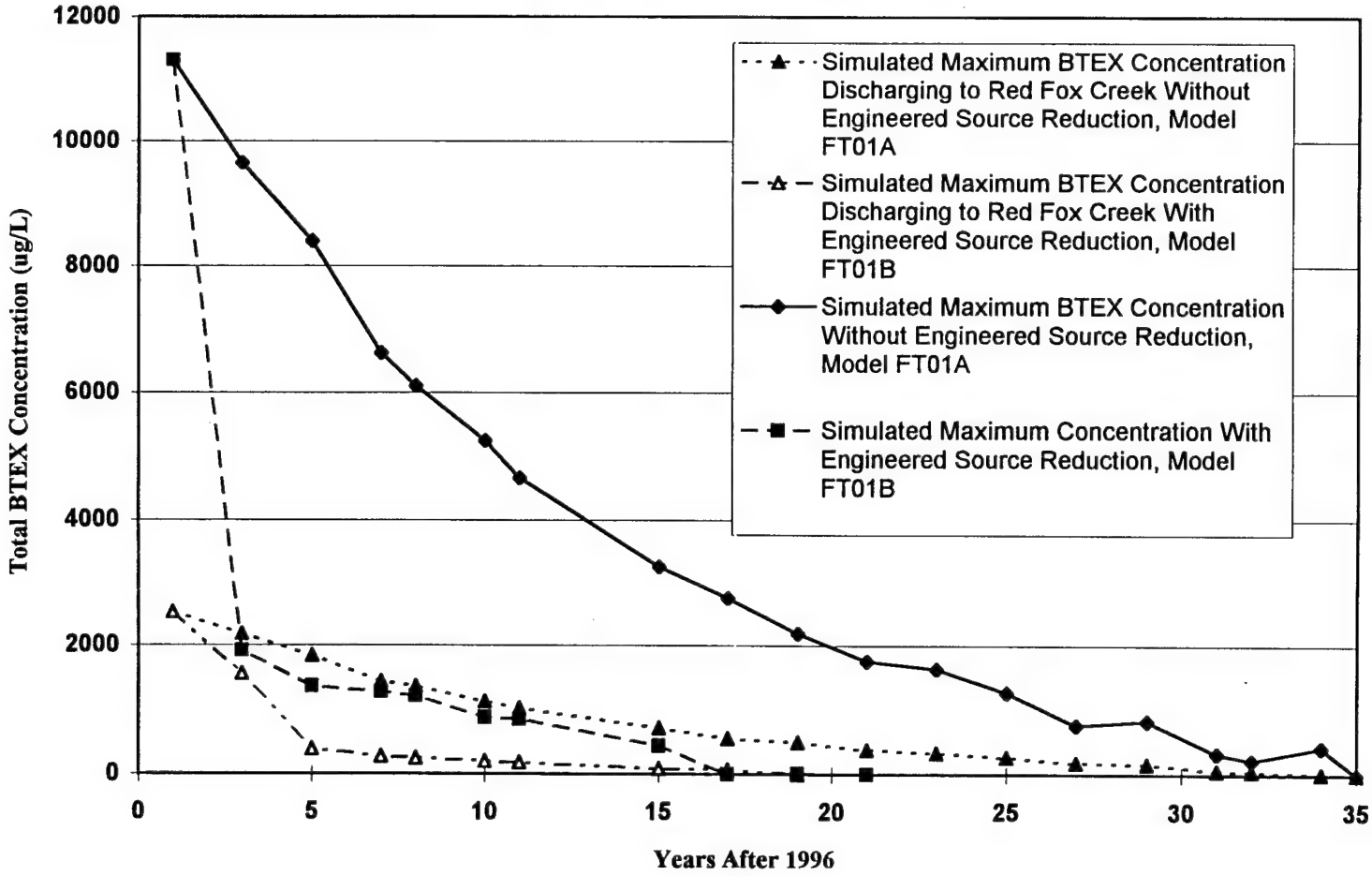
To illustrate the impact of engineered source reduction activities upon dissolved BTEX migration at the RAPCON site, model FT01B incorporated more rapidly decreasing BTEX loading rates, assuming that the RAPCON source area would be excavated during calendar year 1997. As described in Section 5.6 for Site FT01, it is assumed that 20 percent of the contamination source would remain following excavation, and would weather at a geometric rate of 8 percent per year. Because the assumptions for the Site FT01 plume were not changed from models FT01A to FT01B, the simulation results for this plume are identical for both models.

Model FT01B was run for a period of 30 years beyond 1995. As shown on Figure 5.12, model FT01B predicts that the source removal action would cause maximum dissolved BTEX concentrations in the RAPCON plume to decrease dramatically compared with predicted rates for natural attenuation alone. The model predicts that the RAPCON plume would be completely biodegraded following simulation year 20 (calendar year 2015). Figure 5.12 also indicates that BTEX concentrations discharging to Red Fox Creek would undergo a similar decrease, declining to zero by simulation year 17 (calendar year 2012).

5.6.3 Engineered RAPCON Source Reduction and Air Sparging (Model FT01C)

To illustrate the impact of both engineered source reduction at the RAPCON site and installation of an air sparging curtain across the RAPCON plume near the upgradient bank of Red Fox Creek, model FT01C incorporated oxygen injection wells in model grid cells (13,24), (14,24), and (15,24) (Figure 5.3). To determine the proper amount of oxygen addition, varying amounts of DO were added to three adjacent model grid cells in a nearby uncontaminated portion of the modeled area [cells (6,20), (7,20), and (8,20) (Figure 5.3)] until the DO content of the groundwater in the cells increased by an average of nearly 3 mg/L over a 5-year period. The three test cells had the same assigned transmissivity value as the cells targeted for air sparging within the RAPCON BTEX plume. Based on results obtained with a sparging system in a shallow, unconfined, sand and gravel aquifer in Denver, Colorado (Ratz, 1993), this degree of oxygen enhancement of the shallow groundwater may be achievable. The same amount of oxygen was then

FIGURE 5.12
SIMULATED TEMPORAL VARIATIONS IN BTEX CONCENTRATIONS IN THE RAPCON SITE MODELS FT01A AND FT01B
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA



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added to cells (13,24), (14,24), and (15.24) (Figure 5.11), and the model was run for a period of 30 years beyond 1995.

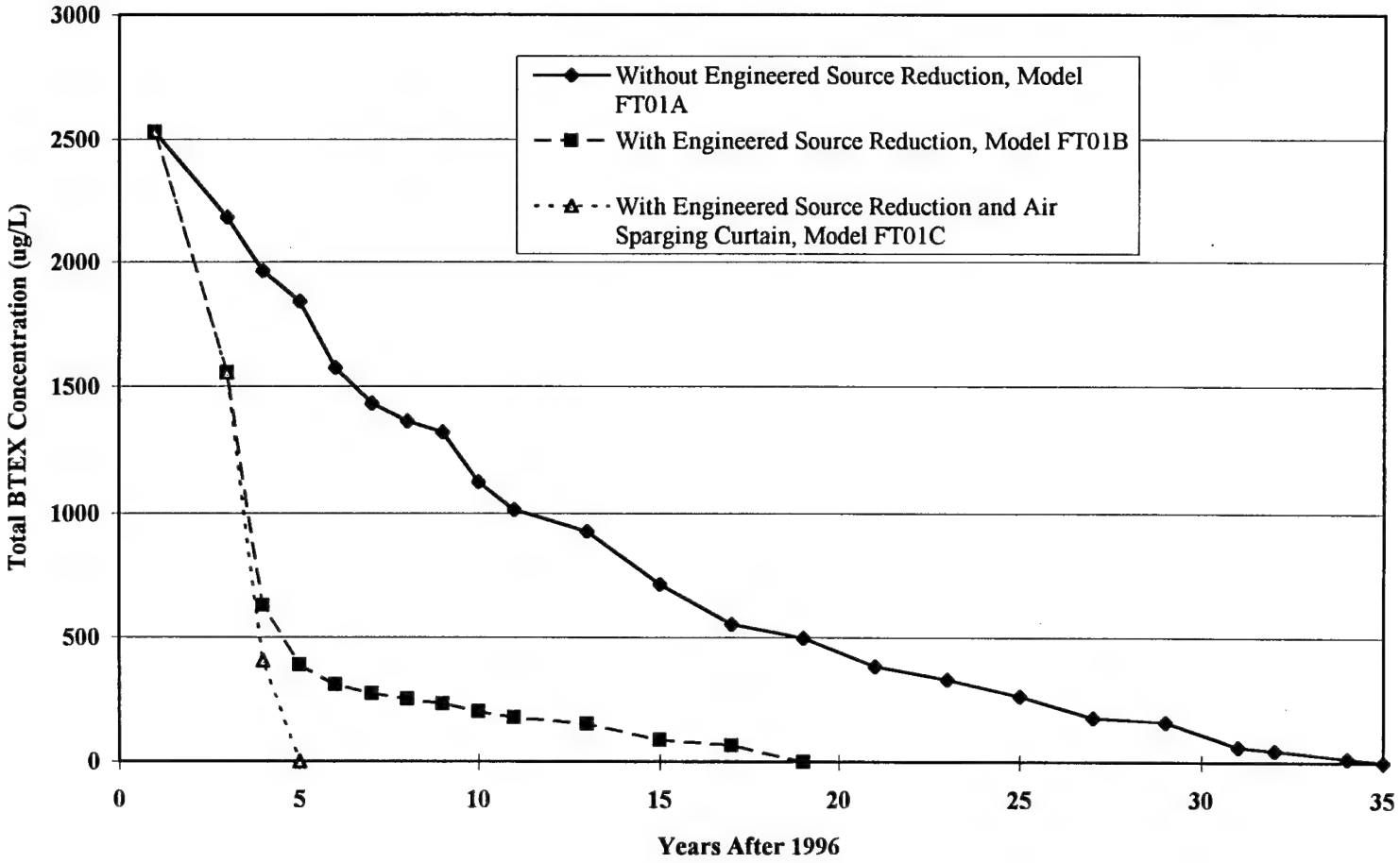
The effect of the simulated air sparging on maximum BTEX concentrations discharging to Red Fox Creek is shown on Figure 5.13. As shown on this figure, the model predicts that, if sparging is initiated late in 1997, BTEX discharge to the creek from the three sparged cells would be eliminated after 1998. This simulation is a simplification of an actual sparge curtain because the model assumes that DO concentrations are uniformly raised through the 40- by 60-foot model grid cells. For this reason, and because sparging efficiency is strongly dependent on sparge well spacing, local stratigraphy, and the degree to which air channeling occurs, the actual sparging efficiency that would be achieved may not be the same as simulated in this model. However, the results of this model suggest that installation of a sparging curtain across the RAPCON plume would significantly decrease discharge of BTEX-contaminated groundwater to the creek. Furthermore, volatilization, which can be a significant contaminant attenuation component in a sparging system, was not simulated by this model. The model results indicate that installation of a sparging curtain in the downgradient portion of the RAPCON plume would not significantly affect dissolved BTEX concentrations in the RAPCON source area, located northeast of the sparged area [e.g., in model grid cells (14,21) and (14,22) (Figure 5.3)].

5.6.4 BTEX Plume Underflow Beneath Red Fox Creek (Model FT01D)

Models FT01A, FT01B, and FT01C assume that the Site FT01 and RAPCON site BTEX plumes discharge to Red Fox Creek, and that underflow beneath the creek is not significant. The validity of this assumption is supported by the low magnitude of BTEX detected in groundwater from monitoring point GP-6, which is on the downgradient side of the creek opposite the RAPCON site (Figure 4.5). However, it is feasible that underflow beneath the creek may occur, especially during dry periods when the water table is relatively low. Therefore, the grid cells south and southwest of the creek were activated in model FT01A in order to simulate the scenario where no discharge to the creek occurs, and 100 percent of the plume migrates beneath the creek 100 percent of the time. This simulation was termed FT01D. To accomplish this, a specified-head boundary was established in the furthest downgradient row of active grid cells (row 39 on Figure 5.3). The resulting water table map is shown in Figure 5.14. Groundwater is simulated to migrate approximately parallel to the long axis of the grid with an estimated lateral hydraulic gradient of 0.002 ft/ft and a transmissivity of 3,000 ft^2/day. Simulated advective groundwater velocities in the newly activated portion of the grid were approximately 0.9 ft/day; simulated advective flow velocities on the upgradient side of the creek generally ranged from 0.3 to 1.1 ft/day. Initial DO concentrations in the newly activated portion of the grid ranged from 1 mg/L along the plume flowpath (model grid rows 12 through 19) to 4.5 mg/L in other model grid rows.

Model FT01D was run for a period of 36 years beyond 1995 to assess the extent to which the BTEX plume would migrate past the creek assuming that discharge did not occur. As with model FT01A, this model assumes that contamination was introduced at the RAPCON site in 1980, and that BTEX source concentrations were constant from 1980 to 1995. Starting after 1995, the source concentrations were reduced at a geometric

FIGURE 5.13
SIMULATED MAXIMUM BTEX CONCENTRATIONS DISCHARGING TO RED FOX CREEK
MODELS FT01A, FT01B, AND FT01C
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA



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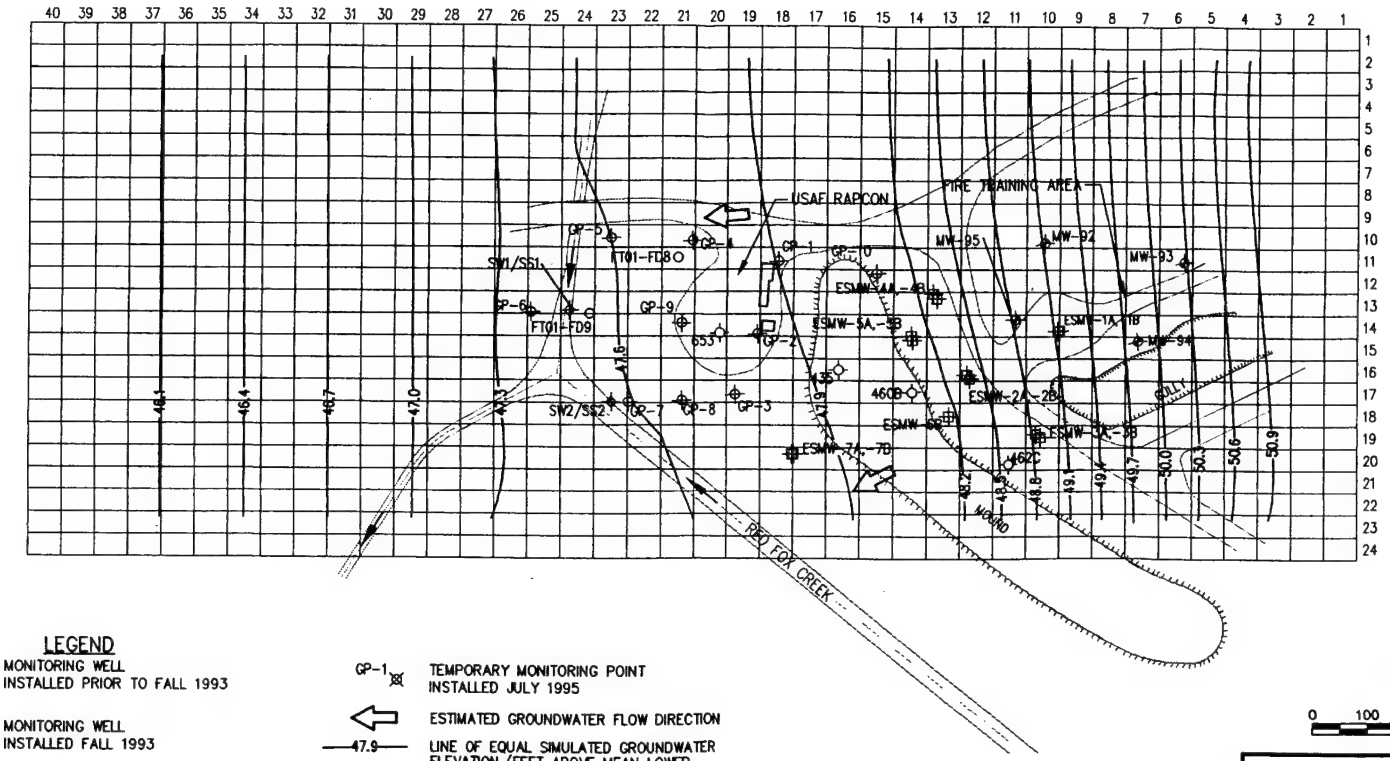

LEGEND

- MW-92 — MONITORING WELL INSTALLED PRIOR TO FALL 1993
- 460B — MONITORING WELL INSTALLED FALL 1993
- ESMW-5A — MONITORING WELL INSTALLED SEPTEMBER 1994
- FT01-FD8 — MONITORING WELL INSTALLED OCTOBER 1994
- SW1/SS1 — SURFACE WATER SAMPLING POINT
- GP-1 — TEMPORARY MONITORING POINT INSTALLED JULY 1995
- ESTIMATED GROUNDWATER FLOW DIRECTION
- 47.9 — LINE OF EQUAL SIMULATED GROUNDWATER ELEVATION (FEET ABOVE MEAN LOWER LOW WATER)

CONTOUR INTERVAL= 0.3 FEET

FIGURE 5.14

SIMULATED GROUNDWATER SURFACE MODEL FT01D

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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rate of 8 percent per year to account for the effects of natural weathering. Because available data support the occurrence of substantial groundwater discharge to Red Fox Creek, this model provides an estimate of the maximum possible downgradient plume travel distance.

The maximum simulated BTEX concentration at the downgradient model boundary (column 39) is depicted on Figure 5.15. The model predicts that BTEX concentrations will peak at 17 μg/L during simulation years 12 through 18, and then decrease steadily, until the modeled concentration is zero at year 35 (2030). Simulated contaminant concentrations upgradient (east and north) of Red Fox Creek were identical to the FT01A simulation.

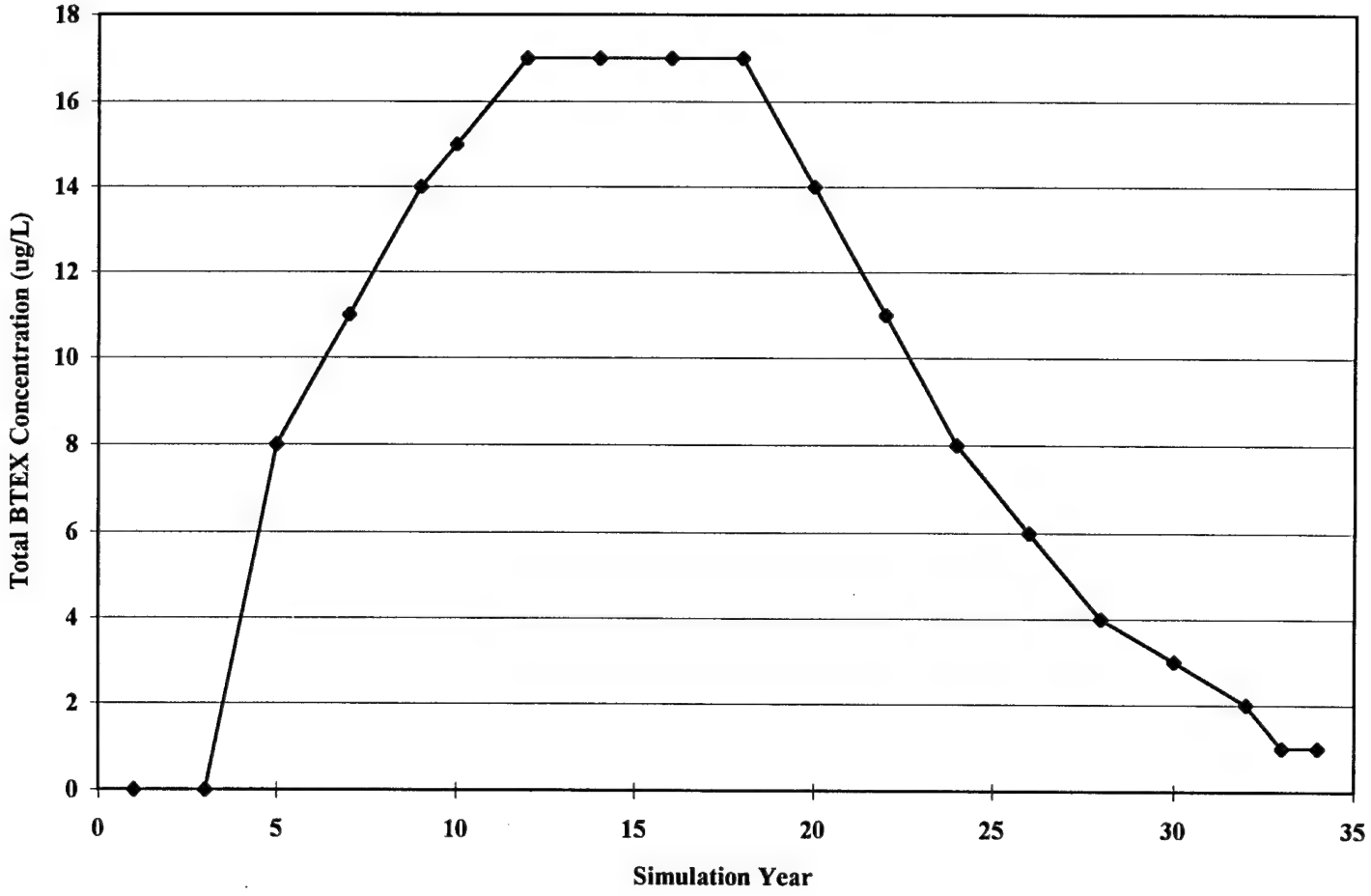
5.7 CONCLUSIONS AND DISCUSSION

Four models were run to simulate a variety of conditions. Model FT01A assumed natural attenuation of BTEX in residual LNAPL in source area soils. Model FT01B was identical to Site FT01A except that it simulated the effects of rapid removal of source area soil contamination at the RAPCON site through excavation. Model FT01C simulated the effects of source soil excavation and installation of an air sparging curtain in the RAPCON BTEX plume bordering Red Fox Creek. Each of these models assumed that groundwater and dissolved contamination discharged to the creek. Model FT01D was identical to FT01A except that groundwater and dissolved contamination were allowed to migrate past the ditch.

The results of the Bioplume II model simulations described in Section 5.6 suggest that the dissolved BTEX plume emanating from FT01 will disperse and degrade relatively rapidly following the 1995 excavation of the source area. The model predicts that this plume will not discharge to Red Fox Creek after 1995, and that the plume will be completely biodegraded after year 2007. The BTEX plume at the RAPCON site is predicted to be more persistent, and discharge of contaminated groundwater to Red Fox Creek may occur for up to 35 years after 1995 if engineered source reduction or plume interception activities are not performed. If source reduction activities are performed at the RAPCON site, then the model predicts that BTEX concentrations discharging to the creek will be substantially reduced, and BTEX discharge will be eliminated approximately 17 years after 1995. If an air sparging curtain is installed across the RAPCON plume along the upgradient edge of the creek, then discharge of BTEX to the creek will be reduced even further, and potentially eliminated altogether, depending on the degree to which DO levels in the shallow groundwater are enhanced and BTEX is volatilized.

The removal of dissolved BTEX compounds predicted by the simulations is largely a function of both aerobic and anaerobic biodegradation and sorption. Influxes of fresh groundwater enhance biodegradation by flushing water containing electron acceptors through the BTEX plume, which is retarded with respect to the advective groundwater velocity. As a result, biodegradation processes are maintained due to the continuous influx of electron acceptors. This is further enhanced by the additional influxes of electron acceptors in the grassy areas where precipitation recharge of the groundwater system occurs.

FIGURE 5.15
SIMULATED MAXIMUM BTEX CONCENTRATION AT DOWNGRADIENT MODEL BOUNDARY
MODEL FT01D
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA



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In all model simulations, several conservative assumptions are incorporated into the model. The use of these conservative model assumptions suggests that natural attenuation of BTEX contamination at the site may exceed model predictions. These conservative assumptions include the following:

The combination of contaminant transport parameters used in the calibrated model was conservative in that BTEX concentrations in downgradient portions of the FT01 plume were overpredicted compared with actual concentrations measured in July 1995. The anaerobic decay rate constant used is lower than common literature values.

Calibrated source concentrations at the RAPCON site, where the BTEX plume has intercepted Red Fox Creek, were higher than observed concentrations. This introduction of extra contaminant mass likely results in the predictions being conservative because additional BTEX mass must be biodegraded to produce the observed results.

In summary, the strong geochemical evidence of anaerobic biodegradation, and the reasonably conservative nature of the Bioplume II models, suggest that natural attenuation will substantially reduce dissolved BTEX concentrations and limit plume migration. However, the model results indicated that the BTEX plume at the RAPCON site will continue to discharge to the creek well into the next century unless source removal and/or plume interception activities are performed. It is important to note that the modeled scenarios incorporate the assumption that additional releases of contaminants to the subsurface through leaks or spills will not occur. The simulated injection wells are intended to represent continued partitioning of BTEX from measured concentrations of mobile and residual LNAPL into the groundwater. Further definition of the contaminant source at the RAPCON site is recommended to support the implementation of a remedial alternative for this site. This recommendation is described in more detail in Section 6.

SECTION 6

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents the development and comparative analysis of three groundwater remedial alternatives for contaminated groundwater emanating from the study area (Site FT01 and the RAPCON site). The intent of this evaluation is to determine if intrinsic remediation of groundwater is an appropriate and cost-effective remedial approach to consider when developing final remedial strategies for the study area, especially when combined with other innovative and/or conventional remedial technologies.

Section 6.1 presents the criteria used to evaluate groundwater remedial alternatives. Section 6.2 discusses the development of remedial alternatives considered as part of this demonstration project. Section 6.3 provides a brief description of each of these remedial alternatives. Section 6.4 provides a more detailed analysis of the remedial alternatives using the defined remedial alternative evaluation criteria. The results of this evaluation process are summarized in Section 6.5.

6.1 REMEDIAL ALTERNATIVE EVALUATION CRITERIA

The evaluation criteria used to identify appropriate remedial alternatives for shallow groundwater contamination at the site were adapted from those recommended by the USEPA (1988) for selecting remedies for Superfund sites [Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-01]. These criteria included (1) long-term effectiveness and permanence, (2) technical and administrative implementability, and (3) relative cost. The following sections briefly describe the scope and purpose of each evaluation criterion. This report focuses on the potential use of intrinsic remediation, source reduction technologies, and plume containment technologies to reduce dissolved BTEX and TCE concentrations in the shallow groundwater below regulatory action levels and to reduce the impact of BTEX and TCE discharge on the surface water in Red Fox Creek.

6.1.1 Long-Term Effectiveness and Permanence

Each remedial technology or remedial alternative (which can be a combination of remedial approaches and technologies such as intrinsic remediation and institutional controls) was analyzed to determine how effectively it will minimize groundwater plume expansion so that groundwater and surface water quality standards can be achieved at a downgradient POC. The expected technical effectiveness based on case histories from other sites with similar conditions also is evaluated. The ability to minimize potential impacts on surrounding facilities and operations is considered. Also, the ability of each remedial alternative to protect both current and potential future receptors from potential risks associated with potentially completed exposure pathways is qualitatively assessed.

This evaluation criterion also included permanence and the ability to reduce contaminant mass, toxicity, and volume. Time to implementation and time until protection is achieved are described. Long-term reliability for providing continued protection, including an assessment of potential for failure of the technology and the potential threats resulting from such a failure, is also evaluated.

6.1.2 Implementability

The technical implementation of each remedial technology or remedial alternative was evaluated in terms of technical feasibility and availability. Potential shortcomings and difficulties in construction, operations, and monitoring are presented and weighed against perceived benefits. Requirements for any post-implementation site controls such as LTM and land use restrictions are described. Details on administrative feasibility in terms of the likelihood of public acceptance and the ability to obtain necessary approvals are discussed.

6.1.3 Cost

The total cost (adjusted to present worth) of each remedial alternative was estimated for relative comparison. An estimate of capital costs, and operating and post-implementation costs for site monitoring and controls is included. An annual adjustment factor of 7 percent was assumed in present worth calculations. The annual adjustment factor is the difference between the rate of inflation and the cost of money (USEPA, 1993b).

6.2 FACTORS INFLUENCING ALTERNATIVES DEVELOPMENT

Several factors were considered during the identification and screening of remedial technologies for addressing shallow groundwater contamination at the site. Factors considered included the objectives of the AFCEE natural attenuation demonstration program; contaminant, groundwater, and soil properties; current and future land uses; and potential receptors and exposure pathways. The following section briefly describes each of these factors and how they were used to narrow the list of potentially applicable remedial technologies to the final remedial alternatives considered the study area.

6.2.1 Program Objectives

The intent of the intrinsic remediation demonstration program sponsored by AFCEE is to develop a systematic process for scientifically investigating and documenting natural subsurface attenuation processes that can be factored into overall site remediation plans. The objective of this program and the specific demonstration at KSA is to provide solid evidence of intrinsic remediation of dissolved fuel hydrocarbons so that this information can be used to develop an effective groundwater remediation strategy. A secondary goal of this multi-site initiative is to provide a series of regional case studies that demonstrate that natural processes of contaminant degradation can often reduce contaminant concentrations in groundwater to below acceptable cleanup standards before completion of potential receptor exposure pathways.

Because the objective of this program is to study natural processes in the saturated zone rather than all contaminated media (e.g., soil, soil gas, etc.), technologies have been

evaluated based primarily on their potential impact on shallow groundwater and phreatic soils. Technologies that can reduce vadose zone contamination and partitioning of contaminants into groundwater also have been evaluated. Many of the source removal technologies evaluated in this section also will reduce soil and soil gas contamination, but it is important to emphasize that the remedial alternatives developed in this document are not intended to remediate all contaminated media. Additional program objectives set forth by AFCEE include cost effectiveness and minimization of waste. Technologies that may best meet these AFCEE criteria include institutional controls, soil vapor extraction, bioventing, bioslurping, passive drain collection, biosparging, and intrinsic remediation. Although alternatives involving soil excavation do not typically meet program objectives for cost effectiveness and waste minimization, excavation is considered a candidate remedial technology at this site because a soil bioventing landfarm is located at KSA within a few miles of the study area. Slurry walls, sheet piling, groundwater pump and treat, carbon adsorption, and *ex situ* biological or chemical treatment of groundwater are not considered attractive technologies for this site.

6.2.2 Contaminant Properties

The site-related contaminants considered as part of this demonstration in the study area are the BTEX compounds and TCE. The primary source of contamination at Site FT01 is petroleum (JP-4 jet fuel) spilled during fire training exercises. A recent excavation of the pit (EMCON, 1996a) has removed the majority of mobile and residual LNAPL contamination in the vadose zone, although low levels of residual LNAPL contamination may be sorbed to perimeter and phreatic soils. The source of contamination present at the RAPCON site is unknown, but is suspected to be a gasoline or other fuel with a high VOC content. Dissolved TCE also is present in the RAPCON source area. The physiochemical characteristics of JP-4, gasoline, TCE, and the individual BTEX compounds will greatly influence the effectiveness and selection of a remedial technology.

Petroleum hydrocarbon mixtures, such as JP-4, are composed of more than 300 compounds with different physiochemical characteristics. JP-4 is classified as an LNAPL with a liquid density of 0.75 g/cc at 20°C (Smith *et al.*, 1981). Many compounds in JP-4 sorb very well to soil and are concentrated in the capillary fringe because the mixture is less dense than water. JP-4 is slightly soluble in water, with a maximum solubility of approximately 300 mg/L. JP-4 is also a primary substrate for biological metabolism. Simultaneous biodegradation of aliphatic, aromatic, and alicyclic hydrocarbons has been observed. In fact, mineralization rates of hydrocarbons in mixtures such as JP-4 may be faster than mineralization of the individual constituents as a result of cometabolic pathways (Jamison *et al.*, 1975; Perry, 1984).

Gasoline is classified as an LNAPL with a liquid density of 0.68 to 0.76 g/cc at 20°C. Because gasoline is less dense than water, LNAPL may become concentrated in the capillary fringe. Some of the individual gasoline constituents can either sorb to the soil matrix, dissolve into groundwater, or volatilize into soil vapor. Constituents in gasoline range from slightly to highly soluble in water. Overall solubility is approximately 200 mg/L. Gasoline is also a primary substrate for biological metabolism (Jamison *et al.*, 1975; Perry, 1984).

The BTEX compounds are generally volatile, highly soluble in water, and adsorb less strongly to soil than other hydrocarbons in a petroleum mixture. These characteristics allow the BTEX compounds to leach more rapidly from contaminated soil into groundwater, and to migrate as dissolved contamination (Lyman *et al.*, 1992). All of the BTEX compounds are highly susceptible to *in situ* degradation by both biotic and abiotic mechanisms.

Benzene is very volatile, with a vapor pressure of 76 millimeters of mercury (mm Hg) at 20°C and a Henry's Law Constant of approximately 0.0054 atmosphere-cubic meters per mole (atm-m^3/mol) at 25°C (Hine and Mookerjee, 1975; Jury *et al.*, 1984). The solubility of pure benzene in water at 20°C has been reported to be 1,780 mg/L (Verschueren, 1983). Benzene is normally biodegraded to carbon dioxide, with catechol as a short-lived intermediate (Hopper, 1978; Ribbons and Eaton, 1992).

Toluene is also volatile, with a vapor pressure of 22 mm Hg at 20°C and a Henry's Law Constant of about 0.0067 atm-m^3/mol at 25°C (Pankow and Rosen, 1988; Hine and Mookerjee, 1975). Toluene sorbs more readily to soil media relative to benzene, but still is very mobile. The solubility of pure toluene in water at 20°C is approximately 515 mg/L at 20°C (Verschueren, 1983). Toluene has been shown to degrade to pyruvate, caetaldehyde, and completely to carbon dioxide via the intermediate catechol (Hopper, 1978; Wilson *et al.*, 1986; Ribbons and Eaton, 1992).

Ethylbenzene has a vapor pressure of 7 mm Hg at 20°C and a Henry's Law Constant of 0.0066 atm-m^3/mol (Pankow and Rosen, 1988; Valsaraj, 1988). Ethylbenzene sorbs more strongly to soils than benzene and toluene (Kenaga and Goring, 1980; Means *et al.*, 1980; Hassett *et al.*, 1983; Fetter, 1993). Pure ethylbenzene is also less soluble than benzene and toluene in water at 152 mg/L at 20°C (Verschueren, 1983; Miller *et al.*, 1985). Ethylbenzene ultimately degrades to carbon dioxide via its intermediate 3-ethylcatechol (Hopper, 1978; Ribbons and Eaton, 1992).

The three isomers of xylene have vapor pressures ranging from 7 to 9 mm Hg at 20°C and Henry's Law Constants of between 0.005 and 0.007 atm-m^3/mol at 25°C (Mackay and Wolkoff, 1973; Hine and Mookerjee, 1975; Pankow and Rosen, 1988). A compilation of literature values for sorption coefficients suggests that xylenes sorb to soil with approximately the same strength as ethylbenzene (Wiedemeier *et al.*, 1995). Pure xylenes have water solubilities of 152 to 160 mg/L at 20°C (Bohon and Claussen, 1951; Mackay and Shiu, 1981; Isnard and Lambert, 1988). Xylenes can degrade to carbon dioxide via pyruvate carbonyl intermediates (Hopper, 1978; Ribbons and Eaton, 1992).

Chlorinated solvents present at the RAPCON site (primarily as TCE) may be more recalcitrant to biodegradation than the BTEX compounds. The primary mechanisms of attenuation for chlorinated solvents once they reach the groundwater are adsorption, biodegradation, and volatilization to the vadose zone. TCE is very volatile, with a vapor pressure of 100 mm of Hg at 20°C and a Henry's Law Constant of approximately 0.0099 atm-m^3/mol at 20°C (Roberts and Dandliker, 1983). Although TCE adsorbs to soil, it is only slightly less mobile and more adsorptive than benzene. The solubility of TCE in water is approximately 1,000 mg/L (Arthur D. Little, 1987). Reductive dehalogenation is typically the primary degradation pathway for TCE (Bouwer, 1994). The process of reductive dehalogenation uses TCE or other similar chlorinated compounds as an electron acceptor and requires the presence of BTEX or natural organic carbon as the primary

carbon source (electron donor). However, reductive dehalogenation was not observed at the study area (Section 4.5.2) based on the absence of sequential, intermediate byproducts. Furthermore, the commingling of BTEX with TCE contamination in groundwater at the RAPCON site suggests that cometabolism may be a potential TCE degradation mechanism. Abiotic hydrolysis products include acetic acid and 1,1,-DCE (Smith *et al.*, 1984).

On the basis of these physiochemical characteristics, intrinsic remediation, soil vapor extraction, bioventing, biosparging, groundwater extraction, excavation, and air stripping technologies could all be effective options for collecting, destroying, and/or treating BTEX and/or TCE at the study site. Remedial technologies such as bioventing and biosparging would be less effective in destroying or treating TCE than the BTEX compounds. Soil remediation technologies would likely be limited to the RAPCON area because the source area at Site FT01 has been excavated. Some of these options are considered less desirable after considering site-specific conditions.

6.2.3 Site-Specific Conditions

Three general categories of site-specific characteristics were considered when identifying remedial approaches for comparative evaluation as part of this demonstration. The first category was physical characteristics such as groundwater depth, hydraulic conductivity, gradient, flow direction, and soil type. The second category was the site geochemistry, or how the site contaminants are interacting with electron acceptors, microorganisms, and other site contaminants. Both of these categories influence the types of remedial technologies most appropriate for the site. The third category involved assumptions about future land use and potential receptor exposure pathways. Each of these site-specific characteristics has influenced the development of remedial alternatives included in the comparative evaluation.

6.2.3.1 Physical Characteristics

Site geology and hydrogeology have a profound effect on the transport of contaminants and the effectiveness and scope of required remedial technologies at a given site. Hydraulic conductivity is perhaps the most important aquifer parameter governing groundwater flow and contaminant transport in the subsurface. The velocity of the groundwater and dissolved contamination is directly related to the hydraulic conductivity of the saturated zone. The estimated average hydraulic conductivity at Site FT01 is 0.0411 ft/min (Section 3.3.3.2), which is characteristic of clean, fine- to medium- grained sand (Freeze and Cherry, 1979). This contributes to a moderately high advective groundwater velocity, estimated at 73 to 402 ft/yr. At the study site, the other significant influences on contaminant transport are the low organic carbon content of the shallow aquifer and the hydraulic connection between the shallow groundwater and a branch of Red Fox Creek to the southwest of the study area.

Although the relatively high hydraulic conductivities of the study area can result in greater plume expansion and migration, this same characteristic also can enhance the effectiveness of other remedial technologies, such as groundwater extraction, biosparging, and intrinsic remediation. For example, it should be less expensive and time-consuming to capture and treat a contaminant plume using a network of extraction wells in an area of high hydraulic conductivity because each well could envelope a larger

area of influence and sustain a higher flow rate. The effectiveness of biosparging also may be increased in highly conductive and/or homogeneous aquifers because of reduced entry pressures and short-circuiting, and increased mixing of sparge air and groundwater. In addition, greater hydraulic conductivity would increase the amount of contaminant mass traveling through a biosparging network. Given a moderately high groundwater velocity, the effectiveness of natural attenuation can increase as a result of enhanced dilution and dispersion of the contaminant mass. The movement of contaminant mass within the subsurface away from the source area also can bring contaminants into contact with a larger mass of electron acceptors, thereby increasing rates of biodegradation. The plume emanating from the FT01 source area likely benefits from increased dilution and dispersion; however, Red Fox Creek south of the study area acts as a natural interception point for much of the contaminant mass emanating from the RAPCON source area, effectively eliminating the beneficial effects of subsurface dispersion and dilution.

Like hydraulic conductivity, the organic carbon content of native phreatic zone soils can affect the effectiveness of remedial alternatives. The TOC of soils across the phreatic surface in the study area have a low organic carbon content (averaging approximately 0.019 percent), and therefore, the soils have a correspondingly low sorptive potential. Nevertheless, this can be useful for technologies such as groundwater pump and treat where contaminant recovery is improved when contaminants are not significantly sorbed to phreatic soil. A low sorptive capacity also means that contaminant velocities are less retarded with respect to groundwater velocity. The small difference between contaminant and groundwater velocity reduces the effectiveness of biodegradation in the source area because there are fewer electron acceptors flowing past the slower moving dissolved contaminant mass.

6.2.3.2 Geochemical Characteristics

To satisfy the requirements of indigenous microbial activity and intrinsic remediation, the aquifer also must provide an adequate and available carbon or energy source (e.g., fuel hydrocarbon contamination), electron acceptors, essential nutrients, and proper ranges of pH, temperature, and redox potential. Data collected as part of the field work phase of this demonstration project and described in Sections 3 and 4 of this TS indicate that this site is characterized by adequate and available carbon/energy sources and electron acceptors to support measurable biodegradation of fuel hydrocarbon contamination by indigenous microorganisms. DO, nitrate, and ferric iron represent sources of electron acceptor capacity for the biodegradation of BTEX compounds at the study area. The average pH in shallow site groundwater ranged between 6.1 to 7.7 standards units in September 1994 and July 1995, which is within the optimal range for biodegradation of 6 to 8 standard pH units (Wiedemeier *et al.*, 1995). As pH values drop below 6 standard units, bacteria populations can be expected to decrease, which in turn would reduce the rate of BTEX biodegradation. Redox potentials ranged from -65 to 260 mV in July 1995 and suggest a groundwater environment that is more oxidizing than reducing. The range of redox potentials suggest that aerobic biodegradation or nitrate reduction would be more likely to occur than sulfate reduction or methanogenesis (consistent with observed geochemical indicator trends discussed in Section 4), and that a strongly reducing environment is not likely available for TCE removal through reductive dehalogenation. Groundwater data presented in Section 4 strongly support the conclusion that aerobic, nitrate-reducing, and iron-reducing processes are reducing BTEX contamination given the current geochemical conditions.

Site geochemical characteristics can also have an effect on the effectiveness of remedial alternatives. For example, the DO introduced through biosparging can also enhance aerobic degradation of the dissolved BTEX mass, particularly at the study site, where oxygen-deficient groundwater is present. Furthermore, groundwater temperatures ranged from 2.5°C to 10°C in September 1994 and July 1995, and saturated groundwater oxygen concentrations are increased because of lower groundwater temperatures. Dissolved oxygen can reach concentrations as high as 12.76 mg/L at 5°C, whereas dissolved oxygen drops to approximately 10.07 mg/L at 15°C [1 atmosphere of pressure (Tchobanoglous, 1991)]. Although not susceptible to aerobic biodegradation, TCE would be susceptible to loss through volatilization as it passed through a biosparging curtain.

Microbe addition was not considered a viable remedial approach for this site on the basis of observed geochemical trends that support that significant microbial activity is likely occurring. Fuel-hydrocarbon-degrading microorganisms are ubiquitous in the subsurface, and as many as 28 hydrocarbon-degrading isolates (bacteria and fungi) have been discovered in different soil environments (Davies and Westlake, 1979; Jones and Eddington, 1968). Indigenous microorganisms have a distinct advantage over microorganisms injected into the subsurface to enhance biodegradation because indigenous microorganisms are well adapted to the physical and chemical conditions of the subsurface in which they reside (Goldstein *et al.*, 1985).

6.2.3.3 Potential Exposure Pathways

A pathways analysis identifies the potential human and ecological receptors that could come into contact with site-related contamination and the pathways through which these receptors might be exposed. To have a completed exposure pathway, there must be a source of contamination, a potential mechanism(s) of release, a pathway of transport to an exposure point, an exposure point, and a receptor. If any of these elements do not exist, the exposure pathway is considered incomplete, and receptors will not come into contact with site-related contamination. Evaluation of the potential long-term effectiveness of any remedial technology or remedial alternative as part of this demonstration project includes determining the potential for pathway completion. If a completed exposure pathway exists (e.g., surface water contact), potential long-term remedial options may still be sufficient to maintain exposure concentrations below regulatory action levels. Establishing site-specific, risk-based cleanup levels is beyond the scope of this TS.

Assumptions about current and future land uses at a site form the basis for identifying potential receptors, potential exposure pathways, reasonable exposure scenarios, and appropriate remediation goals. USEPA (1991b) advises that the land use associated with the highest (most conservative) potential level of exposure and risk that can reasonably be expected to occur should be used to guide the identification of potential exposure pathways and to determine the level to which a site must be remediated.

The contaminant source areas at the study area consist of vadose zone and phreatic soils containing potential residual LNAPL along the periphery and bottom of the source area excavation in the former fire training pit, and residual and/or mobile LNAPL in vadose soils at the RAPCON site (the extent of which has not yet been delineated). Mobile LNAPL has not been detected in any site monitoring wells; however, a hydrocarbon sheen on water was previously detected in Red Fox Creek in 1994 (EMCON, 1996b). Shallow groundwater is expected to serve as the predominant release

and transport mechanism. The majority of shallow groundwater at the site discharges to Red Fox Creek located to south and southwest of the study area. On the basis of groundwater elevations (Section 3) and dissolved BTEX concentrations observed in groundwater in July 1995 (Section 4), the majority of groundwater contamination discharging to Red Fox Creek is from the RAPCON site source area. Observed BTEX concentrations (Figures 4.4 and 4.5) and modeling results (Section 5) suggest that contaminant concentrations emanating from the former fire training area are attenuated before discharging to Red Fox Creek (Model FT01A). It is unknown whether BTEX contamination in surface water has been significantly attenuated through dilution and volatilization in Red Fox Creek within several hundred feet of the study area. The study area is located on a remote section of KSA; however, all segments of Red Fox Creek are accessible to the public. Low concentrations of BTEX in monitoring points and wells along the northwestern periphery of the groundwater plume (MW-92, MW-93, GP-4 and FT01-FD8) suggest the presence of a small spill; however, these BTEX concentrations are low compared to groundwater concentrations observed at Site FT01 and the RAPCON site.

TCE also has been detected in several groundwater samples from the RAPCON site, including the sample from monitoring well FT01-FD9 located adjacent to Red Fox Creek. It is probable that TCE is discharging to Red Fox Creek, and that potential human and ecological receptors could be exposed to TCE (and BTEX) groundwater contamination when it discharges into the receiving creek. This potential exposure pathway should be considered when developing appropriate remedial technologies for TCE and the BTEX compounds.

The shallow groundwater at the study area is not used to meet Base or public water supply demands (EMCON, 1994a). Water supplies for King Salmon AFB are drawn from six groundwater wells, two of which are used for potable water supplies. KSA water supply wells are screened in the C-Aquifer, which is at an estimated depth of 200 feet bgs and separated from the surface aquifer by two confining aquitards (Section 3). None of the water supply wells at KSA are downgradient from the study area. Numerous residential wells are screened within the B-aquifer, whose flow pattern is suspected to be southward trending (EMCON, 1994a). Potential residential wells located on the north bank of the Naknek River and south of the northwest/southeast KSA runway (Figure 1.2) are downgradient from site contaminant plumes. Contaminant migration from the study area to potential B-aquifer wells is highly unlikely, because the distance to residential areas is at least several thousand feet to the southwest, and surficial contamination appears to be vertically limited to the A-aquifer (Section 4.5.1.1).

It is likely that both human and ecological receptors currently could come into contact with contamination discharging from the shallow groundwater into the surface water of Red Fox Creek. An ecological and human health risk assessment was prepared for the surface waters of Red Fox Creek as part of the IRP; however, complete risk assessment data were not available during the preparation of this report. A review of the available ecological risk assessment data suggest that fuel-related contaminants from the RAPCON site are bioaccumulating within trophic level 2 and 3 animals indigenous to surface waters of Red Fox Creek (EMCON Alaska, Inc., 1996c). No risk assessment data regarding potential human receptors were available during the preparation of this report.

Interpretation of contaminant distribution maps and groundwater gradient maps suggests that a small percentage of the dissolved BTEX may migrate in the groundwater beyond the Red Fox Creek; however, the predicted impact to potential downgradient potable water wells is minimal. In summary, the use of intrinsic remediation at this site will require that access to the source areas remain restricted, and that restrictions on shallow groundwater and surface water use be enforced in areas downgradient from the site until natural attenuation and/or engineered source removal can reduce contaminants to levels that pose no risk. If source reduction technologies such as soil vapor extraction, bioventing, biosparging, and excavation are implemented, they will have some impact on the short- and long-term land use options and some level of institutional control and worker protection during remediation will be required.

6.2.3.4 Remediation Goals for Shallow Groundwater and Surface Water

State water quality criteria are listed in Table 6.1 for each of the BTEX compounds, total aromatic compounds (as BTEX), and TCE. Federal maximum contaminant levels (MCLs) are adopted as Alaska groundwater and surface water standards for individual compounds. Federal surface water quality criteria for acute exposure of freshwater aquatic organisms also are provided in Table 6.1 (federal criteria for chronic exposures are not available for the listed compounds). Model results suggest that without engineered source removal, BTEX compounds will continue discharging from the groundwater to Red Fox Creek in excess of the state water quality standards for total aromatics (BTEX) of 10 µg/L [Alaska Department of Environmental Conservation (ADEC), 1995] for an estimated 35 years. This means that viable remedial alternatives must be able to achieve state water quality standards or surface water concentrations protective of human health and the environment negotiated with the state on the basis of risk.

Although it is unlikely that aquatic organisms or surface water from Red Fox Creek would be ingested by humans because of the remoteness and the wetland characteristics of the area, ingestion data for the compounds of concern are provided for reference. The state ambient water quality standard of 10 µg/L for total aromatic VOCs and 5 µg/L for TCE will be used at the creek to evaluate the effectiveness, implementability, and cost of remedial alternatives in this TS; however, the acute exposure concentrations suggest that use of state water quality criteria remedial objectives may be conservative with respect to the risk to human health risk. If surface water concentrations protective of human health and the environment can be negotiated with the state on the basis of risk, the time and cost of the proposed remedial alternative (Section 6.5) could potentially be decreased.

This remedial strategy assumes that compliance with promulgated, single-point groundwater remediation goals is not necessary if site-related contamination does not pose a threat to human health or the environment (i.e., the exposure pathway is incomplete).

Thus, the magnitude of required remediation in areas that can and will be placed under institutional control (e.g., source areas at Site FT01 and the RAPCON site) is different from the remediation that is required in areas that may be available for unrestricted use (e.g., Red Fox Creek). Therefore, the primary remedial objective for shallow groundwater is to reduce contaminant concentrations in groundwater discharging to the creek to below state regulatory criteria. To accomplish this, remedial alternatives focus

TABLE 6.1
WATER QUALITY STANDARDS
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Compound	Federal Ambient Water Quality, Fresh Water Acute (µg/L)[a/]	Federal Ambient Water Quality, Ingestion of Organisms (µg/L)[a/]	State Ambient Water Quality Standard (µg/L)
Benzene	5,300	71	5[b/]
Toluene	32,000	29,000	1,000[b/]
Ethylbenzene	17,500	300,000	700[b/]
Total Xylenes	Not Available	Not Available	10,000[b/]
Total Aromatics (BTEX)	Not Available	Not Available	10[c/]
TCE	100	81	5[b/]

[a/] USEPA (1991a).
[b/] Federal MCLs (USEPA, 1993a) are used by the State of Alaska for compound specific groundwater and surface water standards (18AAC80).
[c/] Alaska Water Quality Standards 18AAC70 (ADEC, 1995).

on removing residual and/or mobile LNAPL within the undefined source area at the RAPCON site and treating the BTEX- and/or TCE-contaminated groundwater prior to its discharge to Red Fox Creek southwest of the study area.

In summary, available data suggest that completed exposure pathways involving human and ecological receptors exposed to surface water exist under current conditions. A risk assessment for surface water near the site is in preparation to evaluate site-related risks from this pathway. The data also suggest that there is no other completed potential exposure pathway involving shallow groundwater, provided that use of shallow groundwater as a potable or industrial source of water is prohibited by institutional controls within approximately 1,000 feet of the study area. Thus, institutional controls are likely to be a necessary component of any groundwater remediation strategy for this site. The required duration of these institutional controls may vary depending on the effectiveness of the selected remedial technology at reducing contaminant mass and concentrations in the groundwater.

6.2.4 Summary of Remedial Option Screening

Several remedial options have been identified and screened for use in treating the shallow groundwater at the site. Table 6.2 identifies the initial remedial technologies and approaches considered as part of this demonstration and those retained for detailed comparative analysis. Screening was conducted systematically by considering the program objectives of the AFCEE intrinsic remediation demonstration, physiochemical properties of BTEX and TCE, and other site-specific characteristics such as hydrogeology, geochemistry, land use assumptions, potential receptor exposure pathways, and appropriate remediation goals. All of these factors will influence the technical effectiveness, implementation, and relative cost of technologies for remediating shallow groundwater underlying and migrating from the site. The remedial options retained for development of remedial alternatives and comparative analysis include institutional controls, intrinsic remediation, LTM, biosparging/air sparging, and excavation with onsite treatment at the KSA landfarm.

6.3 BRIEF DESCRIPTION OF REMEDIAL ALTERNATIVES

This section describes how remedial technologies retained from the screening process were combined into three remedial alternatives for the study area. Sufficient information on each remedial alternative is provided to facilitate a comparative analysis of effectiveness, implementability, and cost in Section 6.4.

6.3.1 Alternative 1 - Intrinsic Remediation and Institutional Controls with Long-Term Groundwater and Surface Water Monitoring

Intrinsic remediation is achieved when natural attenuation mechanisms bring about a reduction in the total mass of a contaminant in the soil or dissolved in groundwater. Intrinsic remediation results from the integration of several subsurface attenuation mechanisms that are classified as either destructive or nondestructive. Destructive attenuation mechanisms include biodegradation, abiotic oxidation, and hydrolysis. Nondestructive attenuation mechanisms include sorption, dilution (caused by dispersion and infiltration), and volatilization. The BTEX compounds are subject to both destructive and nondestructive attenuation mechanisms at the study area, whereas TCE is suspected of being subject primarily to nondestructive attenuation mechanisms. In some cases, intrinsic remediation will reduce dissolved contaminant concentrations below numerical concentration goals intended to be protective of human health and the environment. As indicated by the evidence of intrinsic remediation for BTEX and TCE compounds described in Section 4, these processes are occurring at the study area and will continue to reduce contaminant mass in the plume area.

Model FT01A is intended to predict the fate and transport of dissolved BTEX compounds if engineered remedial action is not implemented at the study area. To accomplish this, the model assumed continued releases of fuels to soils in the fire training pit from 1980 to 1992. After 1992, contaminant loading to the fire training pit stopped, and the remaining source gradually weathered (8 percent per year reduction of the source strength) until vadose soils were excavated from the pit in 1995. In 1995, the simulated mass loading of BTEX in the source area at Site FT01 was reduced by 80 percent to account for effects of site excavation. The remaining 20 percent of the simulated BTEX source was then weathered at an annual rate of 8 percent. Because the history of the

TABLE 6.2
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

General Response Action	Technology Type	Process Option	Implementability	Effectiveness	Relative Cost	Retain
Long-Term Monitoring	Periodic Groundwater Monitoring	Confirmation Wells	Six of the proposed 12 LTM wells are available to confirm the progress of remediation. Sufficient space exists for additional wells between the source areas and the creek.	Necessary for all remedia-tion strategies	Low	Yes
		Point-of-Compliance Wells	The probable point-of-compliance has already been impacted. The point-of-compliance (i.e., Red Fox Creek) will need to be monitored to confirm the progress of remediation.	Not possible at this site	Low	No
Institutional Controls	Groundwater Use Control	Land Use Control/Regulate Well Permits	The plume lies within the Base boundary; however, the Base has been closed and the land will eventually be converted to other uses.	Necessary due to uncertain land use	Low	Yes
		Seal/Abandon Existing Wells	No production wells are known to exist in the current or predicted plume area.	Not required at this site	Low	No
		Point-of-Use Treatment	No shallow groundwater is extracted from the plume area for any use.	Poor	Moderate	No
	Public Education	Meetings/ Newsletters	Base closure offices have many information avenues to workers and residents.	Necessary	Low	Yes
Containment of Plume	Hydraulic Controls	Interceptor Trench Collection	Surface water has been impacted by discharge of contaminated groundwater. Because the distance between the source of contamination and the creek is short, the impacted creek segment is limited. Groundwater is very shallow along the creek.	High	Moderate to High	No
		Minimum Pumping/ Gradient Control	Site hydrogeologic conditions (shallow depth to groundwater, heterogeneity) favor passive drain collection (interceptor trenches).	Moderate	High	No
	Physical Controls	Slurry Walls/Grout Curtains	Limited effectiveness. Contaminated groundwater would seek alternate paths over, under, or around the walls enroute to the creek.	Low to Moderate	High	No
		Sheet Piling	Limited effectiveness. Contaminated groundwater would seek alternate paths over, under, or around the walls enroute to the creek.	Low to Moderate	High	No

TABLE 6.2 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

General Response Action	Technology Type	Process Option	Implementability	Effectiveness	Relative Cost	Retain
Containment of Plume (cont.)	Reactive/Semi-Permeable Barriers	Biologically Active Zones	Degradation of BTEX can be stimulated by allowing groundwater to flow through a nutrient-rich barrier. TCE concentrations might be reduced through increased cometabolism with BTEX. New, unproven technology.	Moderate	High	No
In Situ Groundwater Treatment	Biological	Oxygen and/or Nutrient Enhanced Biodegradation (Biosparging)	Differs from biologically active zone in that oxygen and/or nutrients are injected downgradient of plume to limit plume migration by enhancing biodegradation and reducing BTEX concentrations as the plume moves downgradient from the source area. Loss of TCE would be through limited volatilization. Not proven to be more effective than intrinsic remediation.	Moderate	Low	Yes
	Chemical/ Physical	Intrinsic Remediation	A combination of natural biological, chemical, and physical removal mechanisms which occur to varying degrees on every site. Groundwater sampling at the study area indicates that this is an ongoing remediation process.	Moderate	Low	Yes
		Air Sparging (Volatilization)	Injection of air into contaminated aquifer creating a mass transfer of BTEX into air bubbles and into vadose zone. Limited radius of influence and short-circuiting are common problems. TCE would also be volatilized.	Moderate	Low	Yes
Aboveground Groundwater Treatment	Groundwater Extraction	Vertical Pumping Wells	A part of or the entire groundwater plume is pumped by installing numerous wells with submersible pumps. Produces a large volume of water which requires additional treatment.	Moderate	High	No
	Biological	Bioreactors	High flow rates require excessive retention times and large reactors. BTEX is often volatilized in these systems.	Moderate	High	No
	Chemical/ Physical	Air Stripping	Cost-effective technology for removing varying concentrations of BTEX or TCE at higher flow rates. Potential permitting for air emissions.	High	Moderate	No
		Activated Carbon	Cost prohibitive for more concentrated BTEX or TCE. Creates a carbon disposal problem.	High	High (O&M)	No
		UV/Ozone Reactors	High flow rates require excessive retention times and large, expensive reactors.	Moderate	High	No

TABLE 6.2 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

General Response Action	Technology Type	Process Option	Implementability	Effectiveness	Relative Cost	Retain
Aboveground Groundwater Treatment (cont.)	Chemical/ Physical (cont.)	Direct Discharge to Industrial Wastewater Treatment Plant (IWWTP)	Viable option when an IWWTP is readily available and capable of handling BTEX, TCE, and hydraulic loading. IWWTP not available for this site.	High	High	No
Treated Groundwater Disposal	Discharge to IWWTP or Sanitary Sewer	IWWTP	Viable option when an IWWTP is available and capable of handling BTEX, TCE, and hydraulic loading. IWWTP is not available.	High	High	No
		Sanitary Sewer	Viable option when access to sanitary sewer exists and hydraulic loading is acceptable.	High	Low	No
	Treated Groundwater Reinjection	Vertical Injection Wells	Not recommended due to clogging and high maintenance.	Moderate	High	No
		Injection Trenches	Require large trenches and can be subject to injection well permitting.	Moderate	High	No
	Discharge to Surface Waters	Storm Drains	Viable option when a storm drain is available. Generally requires discharge permit. Storm drain is not available.	High	Low	No
Source Removal/Soil Remediation	*In Situ*	Bioventing	Air injection/extraction to increase soil oxygen levels and stimulate biodegradation of fuel residuals. Limited volatilization of TCE.	Moderate	Low	No
		Soil Vapor Extraction	Vapor extraction has been successfully implemented at other sites for both BTEX and TCE. Typically requires off-gas treatment	High	Moderate	No
		Excavation	Viable option when soils can be disposed of and/or landfarmed close to the site. A bioventing landfarm that is operated and maintained by base personnel is located within 1 mile of the study area and can accept excavation wastes.	High	Low to Moderate	Yes
		Soil Washing	Additional pore volumes of water and/or surfactant solution are forced through aquifer material to enhance hydrocarbon partitioning into groundwater.	Low	High	No

TABLE 6.2 (Concluded)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

General Response Action	Technology Type	Process Option	Implementability	Effectiveness	Relative Cost	Retain
Surface Water Treatment	Chemical/ Physical	Air Sparging	Injection of air into creek, creating a mass transfer of BTEX into air bubbles and enhancing biodegradation.	High	Low	No
		Intrinsic Remediation	A combination of natural biological (biodegradation), chemical (photooxidation), and physical (dilution, volatilization) removal mechanisms.	High	Low	Yes

RAPCON site is not well documented, source loading at the RAPCON site during the period from 1980 to 1995 was conservatively maintained at a steady-state rate to approximate the plume shape observed in July 1995. After 1995, contamination at the RAPCON site also was weathered at an annual rate of 8 percent.

Results of model FT01A suggest that the groundwater contaminant plume emanating from the fire training area is largely attenuated prior to discharge to Red Fox Creek, and the groundwater plume will disappear following simulation year 12 (calendar year 2007). However, Red Fox Creek will continue to receive groundwater BTEX contamination from the RAPCON site above the state water quality standard of 10 μg/L for an estimated 35 years (calendar year 2030). At the current estimated discharge rate and concentration, the mass of BTEX discharged to Red Fox Creek amounts to approximately 0.24 kg of BTEX per year. This discharge rate is expected to slowly decrease until complete site remediation of groundwater in the year 2030. The modeling of TCE attenuation is not within the scope of this TS; however, TCE may persist for a similar time period as groundwater BTEX contamination.

Implementation of Alternative 1 would require the use of institutional controls such as land use restrictions and LTM. Land use restrictions may include placing long-term restrictions on soil excavation within the source area, surface water use restrictions, and long-term restrictions on groundwater well installations within and downgradient from the plume area. The intent of these restrictions would be to reduce potential receptor exposure to contaminants by legally restricting activities within areas affected by site-related contamination.

Long-term monitoring would be conducted annually as part of this remedial technology to evaluate the progress of natural attenuation processes and to ensure that remedial objectives are being met. Because contaminated groundwater is discharging to Red Fox Creek, POC wells would not be used. Instead, surface water samples would be collected at four locations upstream, within, and downstream from the area of site groundwater discharge during annual LTM in order to assess the impact of groundwater discharge on the surface water quality of the creek. Although the majority of shallow contaminated groundwater is discharged into Red Fox Creek, long-term groundwater monitoring also will be performed south of the creek to confirm that substantial BTEX and/or TCE mass is not migrating beyond the creek.

As a part of LTM, groundwater monitoring would be performed at 14 wells. The wells would be chosen to monitor the BTEX plume extending from Site FT01 (6 wells) and the BTEX/TCE plume extending from the RAPCON site (8 wells). Additional details (including monitoring locations) for LTM of both surface water and groundwater are provided in Section 7.2. If implementation of the remedial alternative does not result in a decrease in dissolved and discharged contaminant concentrations, additional corrective action may be necessary, and land use restrictions would require reevaluation.

Public education on the selected alternative would be developed to inform Base personnel and residents of the scientific principles underlying source reduction and intrinsic remediation. This education could be accomplished through public meetings, presentations, press releases, and posting of signs where appropriate. Periodic site reviews also could be conducted every year using data collected from the long-term groundwater and surface water monitoring program. The purpose of these periodic

reviews would be to evaluate the extent of contamination, assess contaminant migration and attenuation through time, document the effectiveness of source removal and/or institutional controls at the site, and reevaluate the need for additional remedial actions at the site.

6.3.2 Alternative 2 - Excavation, Intrinsic Remediation, and Institutional Controls with Long-Term Groundwater and Surface Water Monitoring

This alternative is identical to Alternative 1 except that engineered source reduction, in the form of excavation, would be used to reduce the volume of mobile and residual LNAPL within the source area at the RAPCON site. Excavation was selected as a remedial alternative for its immediate effectiveness in reducing soil and groundwater contamination and because excavation could quickly reduce risks to potential receptors at the site. Excavation would involve the removal of contaminated vadose zone soils in the source area down to the groundwater table (approximately 7 to 10 feet bgs). Some residual LNAPL at the periphery of the excavation and in the smear zone below the groundwater table would be expected to remain. Contaminated soils generated during the excavation could potentially be treated in bioventing treatment cells located at KSA to minimize transportation and disposal costs. By reducing the quantity of mobile and residual LNAPL within the source area, excavation would reduce the predicted future discharge of BTEX and TCE to Red Fox Creek and the predicted length of time required for intrinsic remediation to complete groundwater remediation and for surface water contaminants to attenuate.

Prior to conducting excavation activities, a site characterization study should be performed to delineate the extent and type of contamination present at the RAPCON site. This site characterization should consist of a soil gas study to quickly delineate the location of contaminated soils. Analytical soil samples should then be collected in the most contaminated areas and sent to a fixed-base laboratory to quantify the type and magnitude of soil contamination. The potential volume of soils requiring excavation can then be accurately estimated.

To estimate the impact of excavation on the fate and transport of dissolved BTEX in the shallow groundwater as well as the future effects of groundwater discharge to the Red Fox Creek, model FT01B incorporated an instantaneous source removal at the RAPCON site in model simulation year 2 (calendar year 1997). The model estimated an 80-percent removal of leachable soil contamination in 1997. The remaining 20 percent of leachable soil contamination was assumed to weather at a geometric rate of 8 percent per year following the source excavation. Results suggest that maximum dissolved BTEX concentrations will rapidly decrease in the RAPCON source area, and complete biodegradation of the groundwater plume will occur in calendar year 2015 [15 years earlier than was predicted with natural attenuation alone (Alternative 1)]. Contaminant concentrations in groundwater discharging to Red Fox Creek will decline below detectable levels by calendar year 2012.

As with Alternative 1, institutional controls and LTM would be required. LTM wells would be installed in the same locations indicated in the previous section. Groundwater and surface water monitoring also would follow the same schedule. Other source reduction technologies, such as a horizontal bioventing unit, could be used in place of excavation if logistics or regulatory concerns associated with the removal of

contaminated soils are determined to be too great. However, because these technologies require time to reduce soil contamination (i.e., they are not instantaneous), the expected length of time to remediate the dissolved groundwater plume would increase.

6.3.3 Alternative 3 - Biosparging, Excavation, Intrinsic Remediation, and Institutional Controls with Long-Term Groundwater and Surface Water Monitoring

This alternative is identical to Alternative 2 except that a row of biosparging wells would be used to treat shallow groundwater before discharge to Red Fox Creek. The row of biosparging wells would be installed approximately 40 feet upgradient from and parallel to Red Fox Creek, and approximately perpendicular to contaminant migration direction. Such a system would enhance the aerobic biodegradation of fuel hydrocarbons through the introduction of atmospheric oxygen to contaminated groundwater. Biosparging could have the additional benefit of promoting limited volatilization of fuel hydrocarbons and TCE. Biosparging would thereby reduce the impact of site contamination on the Red Fox Creek ecosystem and potential users until intrinsic remediation naturally reduces concentrations of fuel hydrocarbons in the groundwater that would discharge to the creek to levels that would not significantly impact surface water quality.

The estimated impact of biosparging is illustrated by model FT01C. Conservative concentrations of DO (2 mg/L increases in DO concentration) were introduced into groundwater along a 120-foot long biosparging curtain located at the upgradient bank of Red Fox Creek. The model suggests that BTEX discharge to the creek would be eliminated in approximately the same year that biosparging operations are initiated. As a result of local geologic conditions at the site, the groundwater model may be an oversimplification of a biosparging system. However, the results of this model do suggest that despite possible short-circuiting, significant decreases in BTEX-contaminated groundwater can be achieved with modest elevation of groundwater DO concentrations.

As with Alternative 1, institutional controls and LTM would be required. LTM wells would be installed in the same locations as for Alternative 1. Groundwater and surface water monitoring would follow the same schedule as in Alternative 1.

6.4 EVALUATION OF ALTERNATIVES

This section provides a comparative analysis of each of the remedial alternatives based on the effectiveness, implementability, and cost criteria. A summary of this evaluation is presented in Section 6.5.

6.4.1 Alternative 1 - Intrinsic Remediation and Institutional Controls with Long-Term Groundwater and Surface Water Monitoring

6.4.1.1 Effectiveness

The effectiveness of intrinsic remediation was evaluated through Bioplume II modeling presented in Section 5. Model FT01A assumes that site remediation relies entirely on natural attenuation mechanisms. Results of the model suggest that significant

concentrations of BTEX are removed from the groundwater system through intrinsic remediation. The groundwater plume emanating from the fire training pit was not predicted to pose a discharge threat to Red Fox Creek after the year 1995. The plume is quickly diminishing in concentration and is predicted to disappear by the year 2007. The groundwater plume emanating from the RAPCON site also is being reduced through natural attenuation. Groundwater BTEX concentrations at the RAPCON site are decreased by 59 percent between monitoring point GP-9 and monitoring well FT01-FD9 (Figure 4.7). Observed decreases in oxygen and nitrate and an increase in ferrous iron are evidence support that intrinsic bioremediation of BTEX is occurring at the RAPCON site (Section 4). Although intrinsic remediation contributes significantly to remediation at both sites, it may not be adequate to complete the restoration of contaminated groundwater at the RAPCON site or to prevent further degradation of surface water in Red Fox Creek or to mitigate current risk to ecological receptors and/or human receptors. Model FT01A suggests that groundwater BTEX concentrations of several hundred micrograms per liter will continue to discharge to Red Fox Creek for at least another 25 years. Furthermore, concentrations of TCE in groundwater above 100 µg/L are expected to continue to discharge to Red Fox Creek for an undetermined period of time.

As discussed above, model results suggest that natural attenuation mechanisms will significantly reduce contaminant mass in the groundwater; however, without LNAPL source reduction, groundwater discharge concentrations at Red Fox Creek are not predicted to decrease appreciably within the near future. Furthermore, there is a reasonable possibility that the discharge of dissolved BTEX and/or TCE concentrations to the surface water could increase with time. Should increased degradation of the quality of surface water or groundwater occur, the effects would be detected through annual LTM at the 14 proposed groundwater wells (8 proposed LTM wells at the RAPCON site and 6 proposed LTM wells at Site FT01) and 4 surface water locations. While risk may not significantly increase if contaminant discharge to the surface water increases, such an event would indicate that site conditions should be reevaluated.

The effectiveness of this remedial alternative requires that future site activities or construction activities requiring potential soil intrusion within the source area be conducted only by properly protected site workers, and that access to and use of the study area and affected segments of Red Fox Creek remain restricted for the indefinite future. KSA is a closed military Base and indefinite restricted access may not be reasonable. Long-term land use restrictions would be required to ensure that shallow groundwater is not pumped or removed for potable use within a radius of approximately 1,000 feet from the margins of the existing BTEX plumes. Health and safety plans should be enforced to reduce risks from additional excavation or from installing and monitoring additional wells.

Compliance with program goals is one component of the long-term effectiveness evaluation criterion. Alternative 1 would satisfy program objectives designed to promote intrinsic remediation as a component of site remediation and to scientifically document natural processes. This alternative also satisfies program goals for cost effectiveness and waste minimization.

Alternative 1 is based on the effectiveness of natural processes that minimize contaminant migration and reduce contaminant mass over time, and the effectiveness of institutional controls. As described earlier, the discharge of contaminated groundwater to

Red Fox Creek is not predicted to cease in the foreseeable future; rather, there is a significant possibility that the quality of the discharging groundwater will continue to degrade for many years. This means that in the future, the surface water may be subject to higher mass loading of BTEX and LNAPL if source reduction is not implemented. Without source reduction the effectiveness of intrinsic remediation with LTM and long-term land use restrictions is questionable.

6.4.1.2 Implementability

Alternative 1 is not technically difficult to implement. Installation of LTM wells and monitoring of groundwater and surface water are standard procedures. Long-term management efforts would be required to ensure proper sampling procedures are followed. Periodic site reviews should be conducted to confirm the adequacy and completeness of LTM data and verify the effectiveness of this remediation approach. There may also be administrative concerns associated with long-term enforcement of groundwater and surface water use restrictions. Future land use within the source area may be impacted by leaving contaminated soil and groundwater in place. These type of restrictions might impact potential land transfers resulting from base closure. Regulators and the public would have to be informed of the benefits and limitations of the intrinsic remediation option. Educational programs are not difficult to implement. Where the effectiveness of this option has been supported, the initial regulatory reaction to this alternative has been positive. However, at this site, reaction to intrinsic remediation is unlikely to be favorable without the implementation of LNAPL removal in the RAPCON source area.

6.4.1.3 Cost

The cost of Alternative 1 is summarized in Table 6.3. Capital costs are limited to the construction of eight new LTM wells. Included in the $319,000 total present worth cost estimate for Alternative 1 are the costs of maintaining institutional controls and long-term groundwater and surface water monitoring for a total of 35 years. LTM monitoring at Site FT01 is expected to be eliminated after 12 years as a result of complete plume remediation through natural attenuation. It is recommended that conditions at the RAPCON site be reevaluated after 20 years of LTM because model predictions of the fate and transport of groundwater contamination at the study area are conservative, and groundwater remediation may be faster than predicted (Section 5.7). If the groundwater plume at the RAPCON site stabilizes, recedes, or disappears after 20 years of LTM, then monitoring may be reduced to every other year for the remainder of LTM or eliminated.

6.4.2 Alternative 2 - Excavation, Intrinsic Remediation, and Institutional Controls with Long-Term Groundwater and Surface Water Monitoring

6.4.2.1 Effectiveness

The effectiveness of intrinsic remediation and institutional controls with LTM was discussed for Alternative 1 in Section 6.4.1.1. Excavation and *ex situ* treatment of contaminated vadose zone soils at the RAPCON site source area would eliminate the possibility of additional contamination from these soils migrating into the groundwater. Given the model results discussed in Section 5.6, reduction in the mass of BTEX compounds dissolving into groundwater should further limit plume migration and

TABLE 6.3
ALTERNATIVE 1 - COST ESTIMATE
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Capital Costs	**Cost**
Design/Construct 8 LTM Wells	$20,500
Monitoring Costs (per Sampling Event)	**Cost per Event**
Conduct Groundwater Sampling at 6 wells at Site FT01 (every year for 12 years)	$4,500
Conduct Groundwater Sampling at 8 wells and 4 surface water locations at the RAPCON	$8,100
Site (every year for the first 20 years, then every other year for an additional 15 years)	
Maintain Institutional Controls/Public Education (35 years)	$5,000
Project Management and Reporting (35 years)	$7,500
Present Worth of Alternative 1 [a/]	**$319,000**

[a/] Based on an annual adjustment factor of 7 percent (USEPA, 1993b).

ultimately reduce the extent of the dissolved BTEX plume. On the basis of groundwater model FT01B, it is assumed that total BTEX will continue to discharge to Red Fox Creek for 17 years under Alternative 2. Excavation also would substantially decrease the mass of TCE leaching to groundwater from vadose soils; however, the duration of continued TCE discharge to Red Fox Creek has not been determined.

Twenty years of groundwater and surface water monitoring will be required to ensure that intrinsic remediation has uniformly reduced all dissolved BTEX and TCE concentrations to below state water quality standards over the next 20 years. Excavation introduces a greater risk of exposure to fuel hydrocarbons and TCE to workers during excavation of the contaminated soils. Therefore, implementation of this alternative would require enforcement of health and safety plans to reduce risks from exposure to contaminated soils and, possibly, shallow groundwater, during the excavation process.

Alternative 2 should provide reliable, continuous protection with no risk from system failures due to the lack of mechanical systems. The alternative does not comply with program goals to the extent that Alternative 1 does due to the generation of up to 1,100 cubic yards (assuming a 70-foot diameter by 8-foot deep excavation, pending determination of the true size of the source area) of soil requiring treatment and/or disposal. If excavation activities are not compatible with program objectives, a horizontal bioventing system may be installed to achieve similar contamination reductions within a few years of operation.

6.4.2.2 Implementability

Excavation and *ex situ* treatment of the hydrocarbon-contaminated soils is a technically feasible alternative. The RAPCON site is isolated in an area of KSA that experiences very little traffic and is characterized by few structures and little infrastructure. The remote location of the site at KSA will likely increase the difficulty of transporting equipment and materials to the site to perform the excavation. However, product hauling and disposal costs are expected to be reduced because of the close proximity and the potential availability of a soil bioventing landfarm at KSA. The use of the soil bioventing landfarm to receive wastes from the former fire training pit was approved previously (EMCON, 1996a). Prior to excavation activities, a site characterization involving a soil gas study and soil sampling for laboratory analysis should be conducted to define the extent and magnitude of BTEX and TCE soil contamination at the RAPCON site. If soil data collected during the site characterization suggests that TCE contamination is significant, then the appropriateness of excavating and treatment of the TCE contaminated soil at the KSA soil landfarm should be reconsidered. Under this scenario, source removal technologies such as bioventing and/or soil-vapor extraction may be more appropriate. The technical and administrative implementability concerns associated with the intrinsic remediation and LTM component of this remedial alternative are similar to those discussed for Alternative 1.

6.4.2.3 Cost

The estimated capital and operating costs of Alternative 2 are shown in Table 6.4. The total present worth cost of Alternative 2 is $366,000. The cost of Alternative 2 is increased from the costs of Alternative 1 by the addition of site characterization to define the extent of soil contamination at the RAPCON site, soil excavation activities to remove contaminated soils from the RAPCON site, and offsite treatment/disposal of contaminated soils. Dissolved BTEX contamination at the RAPCON site is predicted to disappear in 17 years (Section 5.6.2); however, LTM may continue for up to 20 years to ensure that source excavation and intrinsic remediation is reducing BTEX and TCE discharge to Red Fox Creek. As in Alternative 1, annual LTM at Site FT01 is expected to be eliminated by year 12 because of the complete remediation of the groundwater plume through natural attenuation. If groundwater plumes begin to stabilize, recede, or disappear prior to 20 years of annual LTM, then LTM may be conducted every other year for the remainder of LTM or eliminated as appropriate. The capital expense and annual costs for LTM and institutional controls are assumed to be the same as for Alternative 1, with the exception that under Alternative 2, the estimated duration of these activities has been reduced from 35 to 20 years with a corresponding decrease in cost.

TABLE 6.4
ALTERNATIVE 2 - COST ESTIMATE
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Capital Costs	**Cost**
Design/Construct 8 LTM Wells	$20,500
RAPCON Source Area Characterization	$26,000
Excavate Source Area at RAPCON site	$43,000
Operation, Maintenance, and Monitoring Costs	**Cost per annum or event**
Operate and Maintain Bioventing Soil Piles by Base Personnel (5 years, annual cost that includes bioventing, nutrient addition, and soil sampling)	$3,000
Bioventing Soil Pile Annual Report (every year for 5 years)	$2,000
Conduct Groundwater Sampling at 6 wells at Site FT01 (every year for 12 years)	$4,500
Conduct Groundwater Sampling at 6 wells and 4 surface water locations at the RAPCON Site (per event; every year for 20 years)	$8,100
Maintain Institutional Controls/Public Education (20 years)	$5,000
Project Management and Reporting (20 years)	$7,500
Present Worth of Alternative 2 [a/]	**$366,000**

[a/] Based on an annual adjustment factor of 7 percent (USEPA, 1993b).

The costs of Alternative 2 may be modified if substantial concentrations of soil TCE contamination is discovered during the site characterization of the RAPCON site. Additional cost considerations pertaining to the design, installation, and maintenance of alternative source removal technologies (e.g., bioventing and/or soil-vapor extraction) would alter the present worth estimate of Alternative 2.

6.4.3 Alternative 3 - Biosparging, Excavation, Intrinsic Remediation, and Institutional Controls with Long-Term Groundwater and Surface Water Monitoring

6.4.3.1 Effectiveness

The excavation of contaminated soils from the RAPCON site will substantially reduce the mass of soil contamination leaching to groundwater and the mass of contamination reaching Red Fox Creek. However, residual LNAPL is expected to remain as a smear zone across the water table or within contaminated soils at the periphery of the excavation. This residual LNAPL may continue to leach low concentrations of contamination for many years. Modeled BTEX concentrations discharging to Red Fox Creek are predicted to decline by 85 percent within 4 years of the source excavation at the RAPCON site (Model FT01B, Section 5). Despite the decline in concentrations of contaminated water discharging to Red Fox Creek anticipated after source reduction, the potential impacts on human and/or ecological receptors would not be reduced for at least 2 years [assuming the edge of the estimated source area is approximately 150 upgradient from Red Fox Creek and groundwater velocity is approximately 73 ft/yr (Section 3.3.3.4)], or completely mitigated for many years following. A biosparging curtain would inhibit the discharge of groundwater contamination from the RAPCON site into Red Fox Creek.

The injection of air below the groundwater surface via a biosparging curtain will create a zone of oxygenated groundwater that will enhance the aerobic biodegradation of contaminants intercepting the curtain. Contaminant volatilization is expected to be another potential removal mechanisms for dissolved groundwater contaminants. The excellent homogeneity and porosity of the sandy soils at the site will likely promote reduced pressure heads and reasonable dispersion of air bubbles throughout the aquifer.

Given the Bioplume II model results discussed in Section 5.6, model FT01C suggests that the conservative delivery of 2 mg/L of DO into groundwater is sufficient to completely biodegrade and/or volatilize intercepted groundwater contamination. The true oxygen delivery rates are expected to be higher because of longer residency times at the RAPCON site caused by lower groundwater gradients and because of the increased oxygen saturation concentrations experienced with decreased water temperature (Tchobanoglous, 1991), especially for groundwater in the colder climates of Alaska. As with Alternatives 1 and 2, this alternative would require LTM and institutional controls. Furthermore, the enforcement of health and safety plans to reduce risks to workers during source area excavation and installation of the biosparging system would need to be implemented. Operation of the bioventing cells to treat excavated soils would be as described for Alternative 2. Alternative 3 should provide reliable, continuous groundwater contamination reduction with immediate benefit to Red Fox Creek.

6.4.3.2 Implementability

Installing and operating a biosparging curtain to intercept and contain groundwater contamination at the pumphouse will present additional implementability concerns. The system would consist of approximately 7 biosparging wells, a blower, a power supply, housing for the blower, and groundwater monitoring points. Biosparging equipment is readily available, although the reliability of biosparging technology is not yet proven.

The homogeneity of the site is expected to improve the potential efficiency of the system. Discontinuous permafrost has been encountered at KSA (EMCON, 1994a); however, no discontinuous permafrost has been documented at the study area which may inhibit the operation of a biosparging system. Furthermore, biosparging has been used to remediate diesel contaminated groundwater and soils at a similar site in Cordova, Alaska (Acomb *et al.*, 1995). The technical and administrative implementability concerns associated with excavation, ex situ bioventing treatment of soils, intrinsic remediation, LTM, and institutional control component of this remedial alternative are similar to those discussed in Alternatives 1 and/or 2.

6.4.3.3 Cost

The estimated capital and operating costs of Alternative 3 are shown in Table 6.5. The total present worth cost of Alternative 3 is $663,000. The cost of Alternative 3 is increased from the costs of Alternative 2 by the addition of the biosparging curtain, including system design, construction, operation, and maintenance. For cost analysis, it is assumed that the biosparging system would operate for the duration of proposed LTM, or 20 years. This is based on model FT01C which predicts that groundwater contamination discharging to Red Fox Creek may persist above the state groundwater quality standard of 10 µg/L for total BTEX for the next 17 years. LTM and biosparging would continue for 20 years to ensure that biosparging, excavation, and intrinsic remediation have permanently reduced BTEX (and TCE) discharge to Red Fox Creek. It was assumed that the blower, piping, and biosparging points would be replaced every 5 years for the duration of biosparging operations. The costs for excavation, soil treatment, LTM, and institutional controls are assumed to be the same as for Alternatives 1 and/or 2. If the contaminant plume appears to stabilize, recede, or disappear prior to 20 years of annual LTM, then monitoring may be reduced to every other year for the remainder of monitoring or eliminated as appropriate.

6.5 RECOMMENDED REMEDIAL APPROACH

Three remedial alternatives have been evaluated for remediation of the shallow groundwater at the study area. Components of the alternatives evaluated include biosparging, excavation, intrinsic remediation with LTM of groundwater and surface

water, and institutional controls. Table 6.6 summarizes the results of the evaluation based upon effectiveness, implementability, and cost criteria. Despite the increase in estimated cost from Alternatives 1 and 2, the Air Force recommends Alternative 3 as the most effective option for risk reduction at the study area.

All three alternatives make maximum use of natural attenuation mechanisms to reduce plume migration and toxicity. Alternatives 1 through 3 also rely on natural attenuation to mitigate surface water degradation attributable to discharge of contaminated groundwater into Red Fox Creek. In addition, Alternative 2 would remove mobile and residual LNAPL from the RAPCON Site source area, thereby providing future protection against discharge of contaminated groundwater to the surface water, and decreases the time frame for remediation. Alternative 3 accomplishes all of the above and provides additional

TABLE 6.5
ALTERNATIVE 3 - COST ESTIMATE
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Capital Costs	**Cost**
Design/Construct 8 LTM Wells	$20,500
RAPCON Source Area Characterization	$26,000
Excavate Source Area at Site FT01	$43,000
Initial Design/Construction of Biosparging System	$68,300
Replacement of Biosparging System (per event; every 5 years)	$39,500
Operation, Maintenance, and Monitoring Costs	**Cost per annum or event**
Operate and Maintain Bioventing Soil Piles by Base Personnel (5 years, annual cost that includes bioventing, nutrient addition, and soil sampling)	$3,000
Bioventing Soil Pile Annual Report (annual cost)	$2,000
Conduct Groundwater Sampling at 6 wells at Site FT01 (every year for 12 years)	$4,500
Conduct Groundwater Sampling at 6 wells and 4 surface water locations at the RAPCON Site (every year for 20 years)	$8,100
Maintain Institutional Controls/Public Education (20 years)	$5,000
Project Management and Reporting (20 years)	$7,500
Operate and Maintain Biosparging System (20 years)	$10,900
Biosparging System Annual Report (20 years)	$4,300
Project Management and Reporting (20 years)	$7,500
Present Worth of Alternative 3 [a/]	**$663,000**

[a/] Based on an annual adjustment factor of 7 percent (USEPA, 1993b).

TABLE 6.6
SUMMARY OF REMEDIAL ALTERNATIVES EVALUATION
GROUNDWATER REMEDIATION
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Remedial Alternative	Effectiveness	Implementability	Present Worth Cost Estimate
Alternative 1 - Intrinsic Remediation - Long-Term Monitoring - Institutional Controls	Contaminant mass, volume, and toxicity will be significantly reduced. Approximately 41 percent of dissolved BTEX mass in the groundwater at the RAPCON site source area migrates to and discharges into Red Fox Creek. Impact on Red Fox Creek may persist for decades.	Readily implementable. Long-term management; land, groundwater, and surface water use controls; and monitoring required for up to 35 years. However, the effectiveness of intrinsic remediation should be reevaluated after 20 years of LTM. The conservative nature of the numerical groundwater model predictions suggests that contaminant attenuation may be greater than predicted. If contaminant discharge to Rainbow Creek decreases in the first 20 years, monitoring may be adjusted to every other year for the remainder of LTM. If contaminant concentrations increase or do not decrease, additional remedial work or LTM may be required, for up to 35 years or more.	$319,000
Alternative 2 - Source excavation at RAPCON site - Preliminary Site Characterization - Intrinsic Remediation - Long-Term Monitoring - Institutional Controls	Similar to Alternative 1, with additional source excavation at the RAPCON site. The source area must be delineated by a preliminary site characterization (e.g., soil-gas study and soil sampling) to determine the area and magnitude of soil contamination. The predicted duration of impact to Red Fox Creek would be reduced to 17 years, instead of 35 for Alternative 1.	Readily implementable. Once the source area at the RAPCON site has been delineated, soils can be excavated and disposed of at a bioventing treatment cell located at KSA. Operation, maintenance, and sampling can be provided by airport personnel for reduced cost. Shallow groundwater depths in the area will minimize the volume of soils that will be excavated. Initial estimates on the soil volume requiring excavation is 1,100 cy. Long-term management; land, groundwater, and surface water use controls; and monitoring would be required for the 20 year LTM period.	$366,000

TABLE 6.6 (Concluded)
SUMMARY OF REMEDIAL ALTERNATIVES EVALUATION
GROUNDWATER REMEDIATION
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Remedial Alternative	Effectiveness	Implementability	Present Worth Cost Estimate
Alternative 3 - Biosparging - Source excavation at RAPCON site - Preliminary Site Characterization - Intrinsic Remediation - Long-Term Monitoring - Institutional Controls	Similar to Alternative 2, with the addition of a biosparging curtain placed between the source area and Red Fox Creek to promote biodegradation and volatilization of groundwater contamination intercepting the curtain. Contaminant discharge to Red Fox Creek would almost entirely cease.	Readily implementable. Installation of a biosparging system should present no problems. Drilling required to place air-sparging wells and monitoring point wells. Sparging is estimated to continue for the proposed 20 year LTM period in Alternative 2. Replacement of the biosparging points and blower would occur every 5 years. Long-term management, groundwater, surface water, and land use controls, and monitoring required for duration of LTM period.	$663,000

protection of the surface water through biosparging. Alternatives 2 and 3 require increasingly higher capital expenditures.

All three remedial alternatives are implementable; however, only Alternative 3 is expected to effectively reduce dissolved contaminant migration and toxicity in the short-term. Available information from an ecological risk assessment performed for the segment of Red Fox Creek receiving discharge from the study area suggests that fuel-related contaminants are potentially bioaccumulating within aquatic species of the Red Fox Creek ecosystem (EMCON, 1996c). Therefore, Alternative 3 is the only remedial option that can immediately address known risk to ecological site receptors. Similar information regarding potential impact to human receptors was not available during the preparation of this report. Alternative 3 should be acceptable to the public and regulatory agencies because it is protective of human health and the environment and reduces soil, groundwater, and surface water contamination. Implementation of Alternative 3, or any of the three alternatives, will require land use, groundwater, and possibly surface water use controls to be enforced for approximately 20 years, and perhaps longer depending on the effectiveness of the selected remedial alternative. Groundwater and surface water monitoring would be required for the same period. The proposed LTM period is consistent with federal recommendations that proposed or implemented remedial activities at a site should not exceed 30 years in duration (USEPA, 1988).

The final evaluation criterion used to compare each of the remedial alternatives was cost. Each of the remedial alternatives increases in cost along with the degree of protection to potential receptors at the site. Although the costs of Alternative 3 are higher relative to the other alternatives, the additional costs of Alternative 3 over Alternatives 1 and 2 are justified by the security of knowing that the volume of the contaminant source and the risks to ecological and/or human receptors are being rapidly reduced. Therefore, Alternative 3 is recommended. An LTM plan for surface water and groundwater, including a SAP, is provided in Section 7.

The natural flow of Red Fox Creek potentially provides for surface water quality improvement through volatilization, degradation, and dilution. Therefore, the proposed 20-year LTM period for Alternative 3 may potentially be reduced if risk-based remedial objectives for Red Fox Creek instead of state water quality standards are used. This would potentially reduce the time and cost of implementing the selected remedial alternative, and still be protective of human health and the environment. The use of risk-based concentrations would be negotiated with the state before potential use as remedial action objectives.

SECTION 7

LONG-TERM MONITORING PLAN

7.1 OVERVIEW

At both Site FT01 and the RAPCON site, LTM is a required component of each of the remedial alternatives discussed in Section 6; therefore, a long-term groundwater and surface water monitoring plan must be developed. The purpose of the LTM component of each remedial alternative is to assess site conditions over time, confirm the effectiveness of the remedial alternative, assess compliance with regulatory cleanup goals, and evaluate the need for additional remediation. The LTM plan consists of identifying groundwater and surface water sampling locations and developing a sampling and analysis strategy to monitor progress toward attainment of site-specific remediation goals. The strategy described in this section is designed to verify Bioplume II model predictions and to assess the effectiveness of the selected remedial alternative through measurement of the reduction of contaminant mass, the rate of groundwater remediation, and the impact of groundwater discharge on surface water quality in Red Fox Creek. In the event that data collected under this LTM program indicate that the implemented remedial alternative is insufficient to achieve state water standards (Table 6.1) (or negotiated risk-based standards) at Red Fox Creek, additional engineered controls may be necessary to augment the beneficial effects of intrinsic remediation and the implemented engineered remediation systems.

7.2 LONG-TERM GROUNDWATER MONITORING WELLS

A total of 14 monitoring wells are recommended at the study area as part of LTM. Of these wells, 6 exist and 8 require installation. Proposed LTM well locations are shown on Figure 7.1. Proposed LTM wells will be constructed with 10-foot screens, with approximately 8 feet of screen installed below the water table for shallow wells and the full 10 feet of screen installed below the water table for deep wells.

Monitoring wells are located in the source areas at Site FT01 and the RAPCON site and along the axis of the BTEX plumes that extend from each of these sites toward Red Fox upgradient Creek to the south and southwest. Typical LTM for intrinsic remediation includes wells in background locations, in the anaerobic treatment zone, in the aerobic treatment zone, and downgradient from the aerobic treatment zone; however, these relative locations have been adjusted for LTM wells at the RAPCON site to account for its close proximity to Red Fox Creek and the potential commingling of groundwater contamination from Site FT01 and the RAPCON site. Furthermore, deep LTM wells have been added to monitor the potential vertical migration of TCE within the surface aquifer.

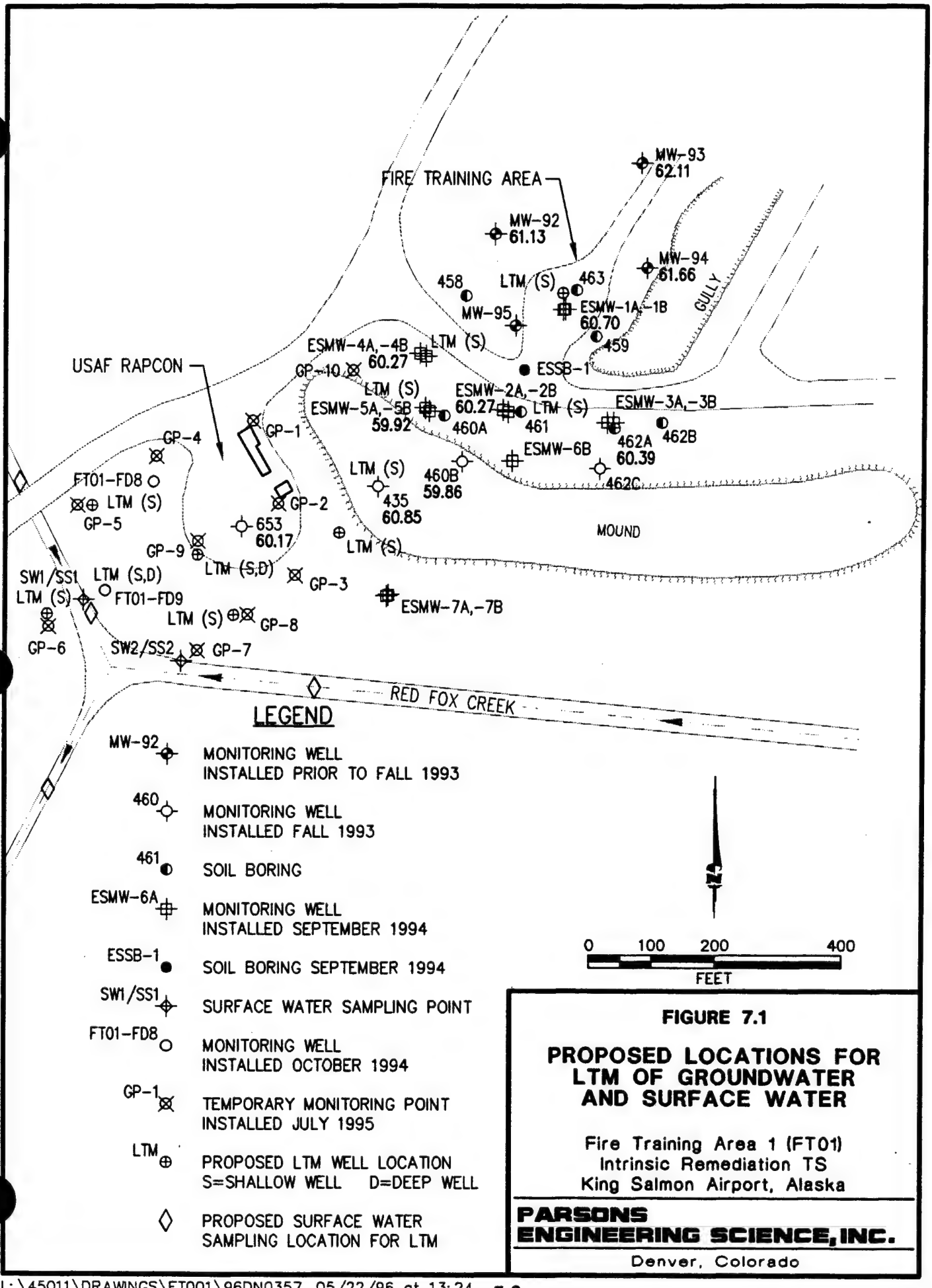

FIGURE 7.1

PROPOSED LOCATIONS FOR LTM OF GROUNDWATER AND SURFACE WATER

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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The proposed LTM wells at Site FT01 consist of one new shallow well and five existing wells (Figure 7.1). Monitoring well MW-93 will be used as an upgradient LTM well upgradient from the fire training pit. The new shallow LTM well will be placed in center of the fire training pit near the former location of ESMW-1A that was destroyed during pit excavation activities. Existing monitoring wells ESMW-2A, ESMW-4A, and ESMW-5A will be used to monitor BTEX concentrations and geochemical trends downgradient from the source area. Monitoring well ESMW-5A is located along the approximate centerline of plume migration. Monitoring wells ESMW-2A and ESMW-4A are located at the lateral edges of the BTEX plume and are intended to monitor potential transverse directional changes of the groundwater plume. Monitoring well 435 will be used to monitor the downgradient edge of the Site FT01 BTEX plume.

The proposed LTM wells associated with the RAPCON site consist of seven new wells and one existing well (Figure 7.1). A new shallow LTM well will be placed upgradient from the RAPCON site and southwest of monitoring well 435. This new LTM well will serve as a background well for the RAPCON site and as a sentry well to monitor the potential expansion of the Site FT01 groundwater plume into the RAPCON site area. New shallow and deep monitoring wells will be placed near the former location of temporary monitoring point GP-9, which is suspected to be in the approximate source area at the RAPCON site. These monitoring wells will be vertically separated by approximately 10 feet in the aquifer to monitor the potential downward migration of TCE and/or BTEX. Two new shallow LTM wells will be placed near monitoring point locations GP-5 and GP-8 to monitor potential changes in the transverse migration of the BTEX/TCE plume. An existing shallow monitoring well (FT01-FD9) will be used to monitor the downgradient portion of the contaminant plume prior to discharge to Red Fox Creek. A new deep monitoring well will be placed adjacent to monitoring well FT01-FD9 (screened approximately 10 feet below the bottom of the screen for monitoring well FT01-FD9) to monitor the potential vertical migration of TCE prior to discharge to Red Fox Creek. A new shallow monitoring well will be placed near monitoring point GP-6 on the southwest side of Red Fox Creek to monitor potential plume migration beneath Red Fox Creek.

7.3 SURFACE WATER SAMPLING LOCATIONS

In order to assess the impact of groundwater discharge, surface water samples will be collected along Red Fox Creek. Surface water samples will replace the use of POC wells. Trends in analytical results from these samples will be used to evaluate the impact of groundwater discharge on the quality of the surface water, and the effects of natural attenuation on contaminant concentrations in the creek.

Surface water samples will be collected at four locations along Red Fox Creek, as illustrated on Figure 7.1. These sampling locations have been selected to assess surface water quality upstream from, within, and immediately downstream from the plume discharge area.

7.4 GROUNDWATER AND SURFACE WATER SAMPLING

To ensure that sufficient contaminant removal is occurring to meet site-specific remediation goals, the long-term groundwater and surface water monitoring plan includes a comprehensive SAP. Groundwater and surface water samples will be collected

annually from LTM wells and surface water sampling locations and analyzed to verify that naturally occurring processes are effectively reducing contaminant mass and mobility. Reductions in toxicity will be implied by contaminant mass reduction.

7.4.1 Sampling Frequency

Each of the LTM wells and surface water sampling locations will be sampled annually for an estimated 20 years under Alternative 3. If the data collected during this time period support the effectiveness of the selected remedial alternative, it may be possible to reduce sampling requirements (e.g., sample every other year) or eliminate in less than 20 years. If the effectiveness of the selected remedial alternative is shown to exceed model predictions, and contaminant concentrations are reduced to below state water quality standards (or negotiated risk-based standards) prior to the completion of proposed LTM, then the frequency of LTM may be reevaluated and/or eliminated.

7.4.2 Analytical Protocol

All LTM wells and surface water sampling locations in the LTM program will be sampled and analyzed to determine compliance with chemical-specific remediation goals and to verify the effectiveness of engineered and naturally-occurring remediation processes at the site. At the beginning of each annual sampling event, water levels will be measured at all site monitoring wells and in Red Fox Creek. Groundwater samples collected from the LTM wells will be analyzed for the parameters listed in Table 7.1. Chlorinated solvent analyses will be performed for samples from LTM wells at the RAPCON site only. Surface water samples will be analyzed for the parameters listed in Table 7.2. A site-specific groundwater and surface water SAP should be prepared prior to initiating the LTM program.

TABLE 7.1
LONG-TERM MONITORING ANALYTICAL PROTOCOL FOR GROUNDWATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Ferrous Iron (Fe^{2+})	Colorimetric A3500-Fe D	Field only	Elevated ferrous iron concentrations may be indicative of the anaerobic biodegradation process of iron reduction.	Annually for 20 Years	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field
Ferrous Iron (Fe^{2+})	Colorimetric HACH® 25140-25	Alternate method; field only	Same as above.	Annually for 20 Years	Collect 100 mL of water in a glass container	Field
Temperature	E170.1	Field only	Metabolism rates for microorganisms depend on temperature.	Annually for 20 Years	N/A	Field
Dissolved Oxygen	Dissolved oxygen meter	Refer to Method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume II model; concentrations less than 1 mg/L generally indicate an anaerobic pathway.	Annually for 20 Years	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen in situ	Field
pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods[a/]	Aerobic and anaerobic processes are pH-sensitive.	Annually for 20 Years	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system.	Annually for 20 Years	Collect 100–250 mL of water in a glass or plastic container	Field
Nitrate	IC method E300 or HACH® Nitraver 5 method	Method E300 is a Handbook method. HACH® method is photometric	Substrate for microbial respiration if oxygen is depleted.	Annually for 20 Years	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base or field (for HACH method)

TABLE 7.1 (Concluded)
LONG-TERM MONITORING ANALYTICAL PROTOCOL FOR GROUNDWATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by biologically mediated reactions; the redox potential of groundwater may range from more than 200 mV to less than -400 mV.	Annually for 20 Years	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Aromatic hydrocarbons (BTEX)	Purge and trap GC method SW8020 or GC/MS method SW8260.	Handbook method; analysis may be extended to higher molecular weight alkylbenzenes	BTEX are the primary target analytes for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance.	Annually for 20 Years	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH $\leq$2	Fixed-base
Chlorinated Volatile Organics	GC/MS method SW8260.	Analysis needed for each LTM location at RAPCON site	Chlorinated solvents (particularly TCE) must be analyzed for regulatory compliance.	Annually for 20 Years	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH $\leq$2	Fixed-base

a/ Protocol analytical methods are those presented by Wiedemeier *et al.* (1995).

TABLE 7.2
LONG-TERM MONITORING ANALYTICAL PROTOCOL FOR SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Temperature	E170.1	Field only	Well development	Annually for 20 Years	N/A	Field
Dissolved Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	Concentrations less than 1 mg/L generally indicate an anaerobic pathway.	Annually for 20 Years	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen in situ	Field
pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods[a/]	Biota and biologic processes are pH-sensitive; general water quality parameter.	Annually for 20 Years	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter.	Annually for 20 Years	Collect 100–250 mL of water in a glass or plastic container	Field
Aromatic hydrocarbons (BTEX)	Purge and trap GC method SW8020 or GC/MS method SW8260	Handbook method; analysis may be extended to higher molecular weight alkylbenzenes	BTEX are the primary target analytes for monitoring impacts of groundwater discharging into surface water; BTEX concentrations must also be measured for regulatory compliance.	Annually for 20 Years	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤ 2	Fixed-base
Chlorinated Volatile Organics	GC/MS method SW8260.	Analysis needed for each surface water sample.	Chlorinated solvents (particularly TCE) must be analyzed for regulatory compliance.	Annually for 20 Years	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤ 2	Fixed-base

[a/] Protocol analytical methods are those presented by Wiedemeier *et al.* (1995).

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

This report presents the results of a TS conducted to evaluate the use of intrinsic remediation for remediation of fuel-hydrocarbon-contaminated groundwater in the vicinity of Site FT01 at KSA in King Salmon, Alaska. Soil and groundwater contamination was also identified at the RAPCON site (southwest of Site FT01) during site characterization activities performed as part of this TS; therefore, the RAPCON site was included as part of the study area for this TS. TCE contamination commingled with groundwater BTEX contamination at the RAPCON site was included in the evaluation and selection of remedial alternatives. Soil, groundwater, and surface water contamination associated with Site FT01 or the RAPCON site were evaluated.

The finite-difference groundwater model Bioplume II was used in conjunction with site-specific geologic, hydrologic, and laboratory analytical data to simulate the migration and natural attenuation of fuel hydrocarbon compounds dissolved in groundwater migrating from the study area. To collect the data necessary for the intrinsic remediation demonstration, Parsons ES researchers collected soil and groundwater data in two site characterization events conducted in September 1994 and July 1995. In addition, surface water and sediment samples were collected from Red Fox Creek in July 1995. Physical and chemical data collected under this program were supplemented (where necessary) with data collected during previous site characterization events.

Comparison of BTEX, electron acceptor, and biodegradation byproduct isopleth maps for the study area provides strong qualitative evidence of the biodegradation of BTEX compounds (Section 4.5.2). Geochemical data strongly suggest that biodegradation of fuel hydrocarbons is occurring at the site via aerobic biodegradation, denitrification, and iron reduction. Comparison of dissolved BTEX maps for the study area from the sampling periods in September 1994 and July 1995 shows a 1,500-µg/L decrease in the maximum BTEX concentration at the Site FT01 source area. Furthermore, BTEX concentrations along the centerline of the groundwater plume at Site FT01 generally decreased between September 1994 and July 1995. The observed reductions in groundwater BTEX concentrations are historic evidence of plume attenuation and the receding threat of the groundwater plume associated with Site FT01. Chlorinated organic compounds were not detected at Site FT01 in September 1994 or July 1995.

Analysis of the groundwater plume at the RAPCON site suggests that the BTEX and TCE plume may currently be stable, although historic data to support this conclusion are incomplete. In July 1995, measured BTEX concentrations in Red Fox Creek exceeded state water quality standards; however, the potential rapid attenuation of contamination through

dilution, volatilization, and biodegradation in creek segments downstream from the site were not assessed, and it is not known how far downstream in the creek elevated BTEX/TCE concentrations persist.

Site-specific geologic, hydrologic, and laboratory analytical data were used in the Bioplume II numerical groundwater model to simulate the effects of advection, dispersion, sorption, contaminant loading, and biodegradation on the fate and transport of the dissolved BTEX plumes beyond 1995. Extensive site-specific data were used for model calibration and implementation. The excavation of the fire training pit at Site FT01 that occurred from June through August 1995 was incorporated into the model design. Model parameters that could not be obtained from existing site data were estimated using widely accepted literature values for soils similar to those found at the site. Conservative groundwater flow and contaminant transport parameters were used to construct the Bioplume II models for this study, and therefore, the model results presented herein represent conservative scenarios. Modeling the fate and transport of groundwater TCE contamination was beyond the scope of this TS.

For one simulation (model FT01A), it was assumed that natural weathering of the source areas at Site FT01 and the RAPCON site would persist for the duration of the simulation. This scenario suggests that BTEX-contaminated groundwater emanating from the RAPCON site will continue to discharge to Red Fox Creek at concentrations that potentially exceed state water quality standards for decades. Model FT01A predicts that approximately 240 grams per year of BTEX is currently discharging to the creek. The groundwater plume at Site FT01 is not considered to be a threat beyond 1995, and is predicted to disappear within 12 years (calendar year 2007). Model FT01B simulates the effects of source excavation at the RAPCON site during which 80 percent of the mobile and residual LNAPL was assumed to be removed from the site. The remaining LNAPL would continue to leach to groundwater and weather at an estimated rate of 8 percent per year. Under this scenario, maximum dissolved BTEX concentrations in the source area and at the edge of Red Fox Creek would substantially decrease within the first few years following excavation. The time required for site remediation with excavation is predicted to be approximately half of the time required for natural attenuation alone (17 and 35 years, respectively). Model FT01C is similar to model FT01B, except a simulated biosparging curtain was placed parallel to Red Fox Creek, between the creek and the RAPCON site source area, to treat contaminated groundwater before it discharges to the creek. This more aggressive remediation scenario is predicted to immediately remove almost all dissolved BTEX and TCE contamination prior to discharge to Red Fox Creek.

The results of this study suggest that remediation by natural attenuation of BTEX compounds is occurring at the study area; however, it is insufficient to prevent continued discharge of contaminated groundwater to Red Fox Creek from the RAPCON site in the near future. Red Fox Creek flows throughout most of the year, which is important in maintaining dilution and volatilization losses that help attenuate groundwater contamination discharging to the creek. However, contaminant concentrations in surface water in Red Fox Creek are currently above state quality standards (Table 6.1). Furthermore, available ecological risk assessment data suggest a fuel-hydrocarbon bioaccumulation hazard to aquatic species indigenous to Red Fox Creek. The current RAPCON site impact on Red Fox Creek requires that more aggressive measures be taken to remediate the study area than reliance on intrinsic remediation alone. Therefore, the Air Force recommends that the implementation of a

remediation strategy that includes a characterization of the RAPCON source area, excavation or source area soils with treatment at a nearby bioventing landfarm, biosparging, intrinsic remediation, LTM, and institutional controls in order to reduce risk to human health and the environment and rapidly achieve state regulatory standards (remedial Alternative 3). Institutional controls such as restrictions on shallow groundwater use, access to the study area, and access and use of the impacted segment of the creek would limit completion of receptor exposure pathways while site remediation was in progress. If excessive concentrations of TCE are detected in excavated soils from the RAPCON site, the appropriateness of using the bioventing landfarm to treat and dispose of excavation wastes should be reevaluated.

To verify the results of the Bioplume II modeling effort, and to ensure that the selected remediation is progressing at rates sufficient to meet objectives, groundwater from 14 LTM wells should be sampled and analyzed annually for the parameters listed in Table 7.1. In addition, four surface water locations should be sampled concurrently and annually for the parameters listed in Table 7.2. Figure 7.1 shows the proposed locations for the LTM wells and surface water sampling locations. The proposed remedial objectives for groundwater and surface water quality are the state water quality standards for BTEX and TCE. However, risk-based remedial water quality standards may be higher than state water quality standards, and their use could potentially reduce the time frame required for biosparging and LTM. The use of risk-based remedial water quality values as cleanup goals would be negotiated with the state. All LTM and surface water sampling locations should be sampled annually for an estimated 20 years during a season that will minimize the possibility of frozen stream conditions. If the groundwater plume is observed to stabilize, recede, or disappear based on LTM data, then the sampling frequency for LTM may be reduced to every other year, or eliminated as appropriate. At the end of 20 years, sampling will cease, decrease in frequency, or will continue, as dictated by the analytical results.

SECTION 9

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APPENDIX A

BOREHOLE LOGS, MONITORING WELL INSTALLATION RECORDS, SURVEY RESULTS, AND SLUG TEST RESULTS

BOREHOLE LOGS

GEOLOGIC BORING LOG

BORING NO.:	ESSB-1	CONTRACTOR:	AIR FORCE	DATE SPUD:	9/19/94
CLIENT:	AFCEE	RIG TYPE:	CME 55	DATE CMPL.:	9/19/94
JOB NO.:	722450.11	DRLG METHOD:	HOLLOW STEM AUGER	ELEVATION:	60.89 FEET ABOVE MLLW
LOCATION:	KING SALMON AFS	BORING DIA.:	10 INCH OD	TEMP:	40 F
GEOLOGIST:	KC	DRLG FLUID:	NONE	WEATHER:	WINDY

COMMENTS: BACKGROUND PID= 2.7 ppm

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	WKSPC PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1											
	5											
	10											
▼	15		SP	Dark brown, fine- to medium-grained SAND. Subangular to subrounded grains. Turning grey at 14.5 feet bgs. Saturated at 15 feet bgs.		11-16	CORE	2 3 2 4 4	3.7			
	20											
	25											
	30											
	35											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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GEOLOGIC BORING LOG

BORING NO.: ESMW-1B
CONTRACTOR: AIR FORCE
DATE SPUD: 9/14/94
CLIENT: AFCEE
RIG TYPE: CME 55
DATE CMPL.: 9/14/94
JOB NO.: 722450.11
DRLG METHOD: HOLLOW STEM AUGER
ELEVATION: 60.49 FEET ABOVE MLLW
LOCATION: KING SALMON AFS
BORING DIA.: 12 INCH OD
TEMP: 45 F
GEOLOGIST: KC
DRLG FLUID: NONE
WEATHER: RAIN
COMMENTS: BACKGROUND PID= 2.7/1.6 ppm

Elev (ft)	Depth (ft)	Profile	USCS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	WKSPC PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1		SP	Brown, fine to medium-grained SAND with silt. Some gravel present.		0-2	CONTINUOUS CORE	1 1 2 2	2.7	2.7		
				SAA with less gravel		2-4		3 3 3 3	2.7			
	5					4-6		2 4 4 3	2.7			
				SAA. Color turning to grey-brown.		6-8			2.7			
				SAA turning grey at 9.5 feet bgs. Increased moisture.		8-10			2.7			
▼	10			SAA with strong hydrocarbon odor. Saturated at 10.2 feet bgs.		10-12			8.3			
						12-14		.5 .5 .5 .5	631			
	15			Hydrocarbon sheen visible.		14-16		1 1 1 1	777			
				Black fluid present, possibly hydrocarbon.		16-18			637			
				SAA with decreased odor. Color turning brown at 19 feet bgs.		18-20			487			
	20			No recovery.		20-22			171.6			
						22-24				11.9		
	25					24-26			113			
						26-28			14.9	2.7		
						28-30			1.6			
	30			SAA with increased compaction.		30-32			8.3			
						32-34		2 2 2 3	1.6	2.7		
	35					34-46						

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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GEOLOGIC BORING LOG

BORING NO.:	ESMW – 1B	CONTRACTOR:	AIR FORCE	DATE SPUD:	9/14/94
CLIENT:	AFCEE	RIG TYPE:	CME 55	DATE CMPL.:	9/14/94
JOB NO.:	722450.11	DRLG METHOD:	HOLLOW STEM AUGER	ELEVATION:	60.49 FEET ABOVE MLLW
LOCATION:	KING SALMON AFS	BORING DIA.:	12 INCH OD	TEMP:	45 F
GEOLOGIST:	KC	DRLG FLUID:	NONE	WEATHER:	RAIN
COMMENTS:	BACKGROUND PID = 2.7/1.6				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36		SP	No Sample		36–38	CONTINUOUS CORE					
				SAA		38–40						
	40			Bottom of Hole at 39.5 feet bgs								
	45											
	50											
	55											
	60											
	65											
	70											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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GEOLOGIC BORING LOG

BORING NO.: ESMW-2B | CONTRACTOR: AIR FORCE | DATE SPUD: 9/15/94
CLIENT: AFCEE | RIG TYPE: CME 55 | DATE CMPL.: 9/15/94
JOB NO.: 722450.11 | DRLG METHOD: HOLLOW STEM AUGER | ELEVATION: 61.09 FEET ABOVE MLLW
LOCATION: KING SALMON AFS | BORING DIA.: 12 INCH OD | TEMP: 40 F
GEOLOGIST: KC | DRLG FLUID: NONE | WEATHER: OVERCAST
COMMENTS: BACKGROUND PID= 1.9 ppm

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	WKSPC PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			No Sample			CONTINUOUS CORE					
	5			Brown, medium- to coarse-grained, pebbly, sandy FILL.		3-5		3 5 7 5	5.7			
				SAA becoming finer with depth.		5-7			5.7	1.9		
			SP	Greyish-brown, fine- to medium-grained subangular to subrounded, SAND.		7-9			1.9			
	10			SAA becoming wet.		9-11		2 2 5 3	1.9			
▼				Saturated at 12.9 feet bgs.		11-13			1.9			
	15					13-15		2 2 4 6	1.9			
				SAA, turning grey at 17 feet bgs.		15-20			1.9			
	20			SAA, turning brown at 22.5 feet bgs.		20-25			1.9 1.9	1.9		
	25					25-30			1.9 1.6	1.9		
	30			No Sample.		30-25			8.3 1.6	2.7		
	35											

NOTES
bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

MONITORING WELL INSTALLATION RECORD

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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GEOLOGIC BORING LOG

BORING NO.: ESMW - 2B
CONTRACTOR: AIR FORCE
DATE SPUD: 9/15/94
CLIENT: AFCEE
RIG TYPE: CME 55
DATE CMPL.: 9/15/94
JOB NO.: 722450.11
DRLG METHOD: HOLLOW STEM AUGER
ELEVATION: 61.09 FEET ABOVE MLLW
LOCATION: KING SALMON AFS
BORING DIA.: 12 INCH OD
TEMP: 45 F
GEOLOGIST: KC
DRLG FLUID: NONE
WEATHER: RAIN
COMMENTS: BACKGROUND PID = 1.9 ppm

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36		SP	SAA		38-40	CONTINUOUS CORE					
	40			Cobbles with silt and sand at 42.5 feet bgs. Top of confining layer.		36-38						
	45			Bottom of hole at 45 feet bgs.								
	50											
	55											
	60											
	65											
	70											

NOTES

bgs - Below Ground Surface
GS - Ground Surface
TOC - Top of Casing
NS - Not Sampled
SAA - Same As Above

SAMPLE TYPE

D - DRIVE
C - CORE
G - GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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GEOLOGIC BORING LOG

BORING NO.: ESMW-3B
CONTRACTOR: AIR FORCE
DATE SPUD: 9/16/94
CLIENT: AFCEE
RIG TYPE: CME 55
DATE CMPL.: 9/16/94
JOB NO.: 722450.11
DRLG METHOD: HOLLOW STEM AUGER
ELEVATION: 60.49 FEET ABOVE MLLW
LOCATION: KING SALMON AFS
BORING DIA.: 10 INCH OD
TEMP: 45 F
GEOLOGIST: KC
DRLG FLUID: NONE
WEATHER: OVERCAST
COMMENTS: BACKGROUND PID= 3.7 ppm

Elev (ft)	Depth (ft)	Profile	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	WKSPC PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			No Sample. FILL								
										3.7		
	5			Well sorted, sandy, FILL. 4 inch clay layer at 5.5 feet bgs.								
			SP	Brown, fine to medium-grained, subangular to subrounded SAND. Dry.		5–10	CONTINUOUS CORE	8 6 6 6 7 5 5	3.7 3.7			
	10											
▼						10–15			3.7 3.7	3.7		
	15			SAA. Saturated at 14.6 feet bgs.								
						15–20		1 1 2 1 3 3 3 3	3.7 3.7			
	20			SAA								
						20–25			3.7 3.7			
	25			NS								
						25–30						
	30			NS								
						30–35						
	35											

NOTES
bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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GEOLOGIC BORING LOG

BORING NO.: ESMW – 3B
CLIENT: AFCEE
JOB NO.: 722450.11
LOCATION: KING SALMON AFS
GEOLOGIST: KC
COMMENTS: BACKGROUND PID = 3.7 ppm

CONTRACTOR: AIR FORCE
RIG TYPE: CME 55
DRLG METHOD: HOLLOW STEM AUGER
BORING DIA.: 10 INCH OD
DRLG FLUID: NONE

DATE SPUD: 9/16/94
DATE CMPL.: 9/16/94
ELEVATION: 60.49 FEET ABOVE MLLW
TEMP: 45 F
WEATHER: OVERCAST

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36		SP	SAA		35–40	CONTINUOUS CORE					
	40			Bottom of hole at 40 feet bgs.								
	45											
	50											
	55											
	60											
	65											
	70											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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GEOLOGIC BORING LOG

BORING NO.:	ESMW-5B	CONTRACTOR:	AIR FORCE	DATE SPUD:	9/17/94
CLIENT:	AFCEE	RIG TYPE:	CME 55	DATE CMPL.:	9/17/94
JOB NO.:	722450.11	DRLG METHOD:	HOLLOW STEM AUGER	ELEVATION:	51.89 FEET ABOVE MLlw
LOCATION:	KING SALMON AFS	BORING DIA.:	10 INCH OD	TEMP:	40 F
GEOLOGIST:	KC	DRLG FLUID:	NONE	WEATHER:	OVERCAST, RAIN
COMMENTS:	BACKGROUND PID= 2.6 ppm				

Elev (ft)	Depth (ft)	Profile	USCS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	WKSPC PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			No Sample. FILL			CONTINUOUS CORE			3.7		
	5		SP	Brown, fine to medium-grained, subangular to subrounded SAND. Dry.		5-10		6 6	2.6			
	10								2.6			
▼				SAA. Wet at 13 feet bgs.		10-15		6 6 4 6 6 7	7.8	3.7		
	15			SAA. Saturated at 14.5 feet bgs.					7.8			
				SAA, turning grey at 17.5 feet bgs.		15-20			2.9			
	20			SAA with increased pebbles.					2.9			
				3 inch layer of pebbles at 23 feet bgs.		20-25			2.6			
	25			SAA with isolated grey, silty clay lens at 29 feet bgs.				6 4 6 7 8 9	2.6			
						25-30			2.6			
	30			NS								
						30-35						
	35											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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GEOLOGIC BORING LOG

BORING NO.: ESMW - 5B
CLIENT: AFCEE
JOB NO.: 722450.11
LOCATION: KING SALMON AFS
GEOLOGIST: KC
COMMENTS: BACKGROUND PID = 2.6 ppm

CONTRACTOR: AIR FORCE
RIG TYPE: CME 55
DRLG METHOD: HOLLOW STEM AUGER
BORING DIA.: 12 INCH OD
DRLG FLUID: NONE

DATE SPUD: 9/17/94
DATE CMPL.: 9/17/94
ELEVATION: 51.89 FEET ABOVE MLLW
TEMP: 40 F
WEATHER: OVERCAST, RAIN

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36		SP	SAA		35-40	CONTINUOUS CORE					
	40			Bottom of hole at 40 feet bgs.								
	45											
	50											
	55											
	60											
	65											
	70											

NOTES
bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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GEOLOGIC BORING LOG

BORING NO.: ESMW-7B
CONTRACTOR: AIR FORCE
DATE SPUD: 9/10/94
CLIENT: AFCEE
RIG TYPE: CME 55
DATE CMPL.: 9/10/94
JOB NO.: 722450.11
DRLG METHOD: HOLLOW STEM AUGER
ELEVATION: 56.89 FEET ABOVE MLLW
LOCATION: KING SALMON AFS
BORING DIA.: 12 INCH OD
TEMP: 45 F
GEOLOGIST: KC
DRLG FLUID: NONE
WEATHER: RAIN
COMMENTS: NO PID MEASUREMENTS DUE TO EXCESSIVE MOISTURE

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			No Sample			CONTINUOUS CORE					
			SP	Brown, fine to medium-grained SAND with silt. Few pebbles present.		3-5		4 5 6 4				
	5			SAA with 0.5 foot coarse interval at 6 feet bgs.		5-7		3 4 3 3				
▼						7-9		5 3 4 3				
	10			Saturated at 9.1 feet bgs.		9-11		2 2 4 3				
				SAA with 1 foot of heave in auger.		11-13						
	15			SAA with 1.3 feet of heave. 6 inches of recovery.		13-15		2 1 2 3				
						15-17						
						17-19						
	20					19-22						
						22-24						
	25					24-26						
						28-30						
						28-30						
	30			NS		30-33						
				Bottom of hole at 33 feet bgs.								
	35											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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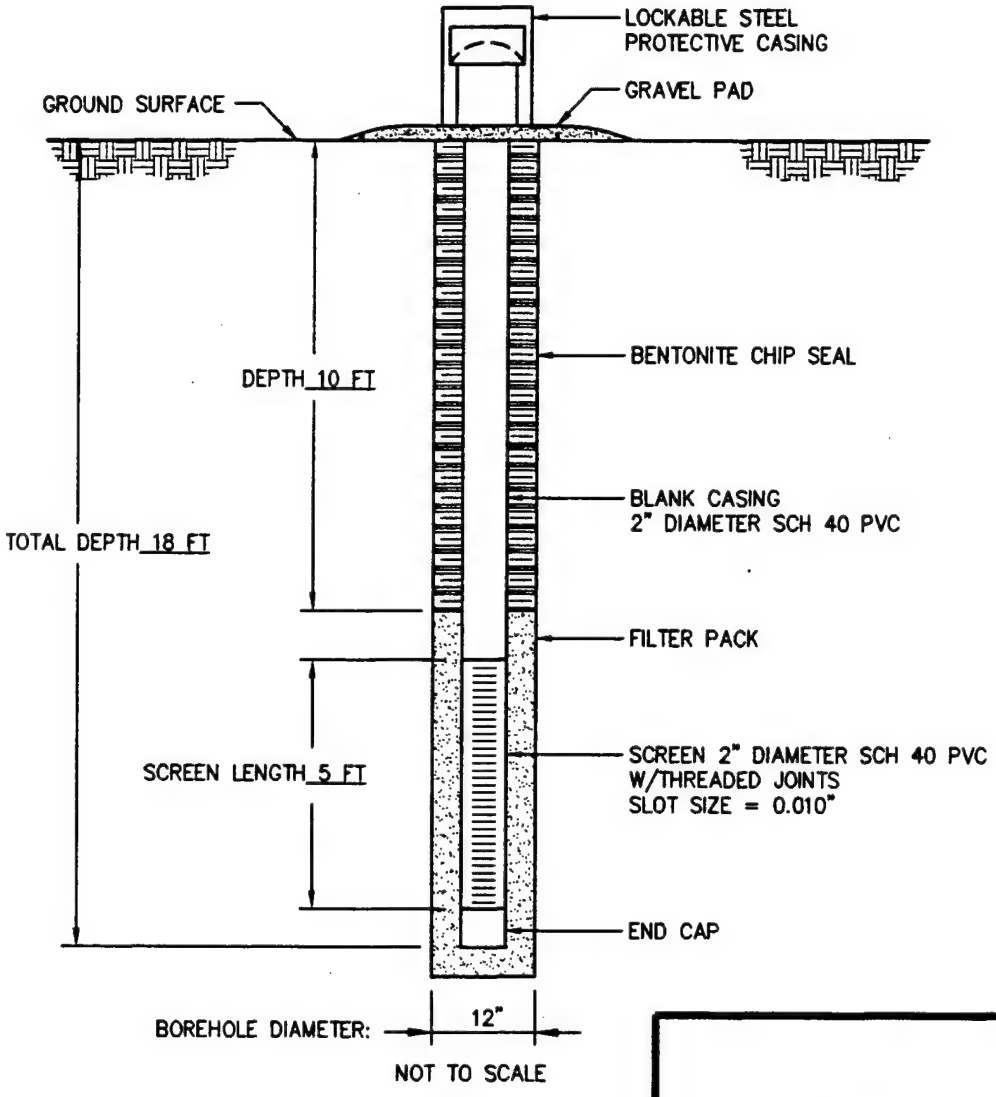
MONITORING WELL INSTALLATION RECORDS

MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -1A
JOB NUMBER 722450.11 INSTALLATION DATE 9/13/94 LOCATION FT-001
DATUM ELEVATION 62.89 FEET ABOVE MLLW GROUND SURFACE ELEVATION 60.49 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 12 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 13.92 FEET BELOW DATUM.
TOTAL WELL DEPTH 20.31 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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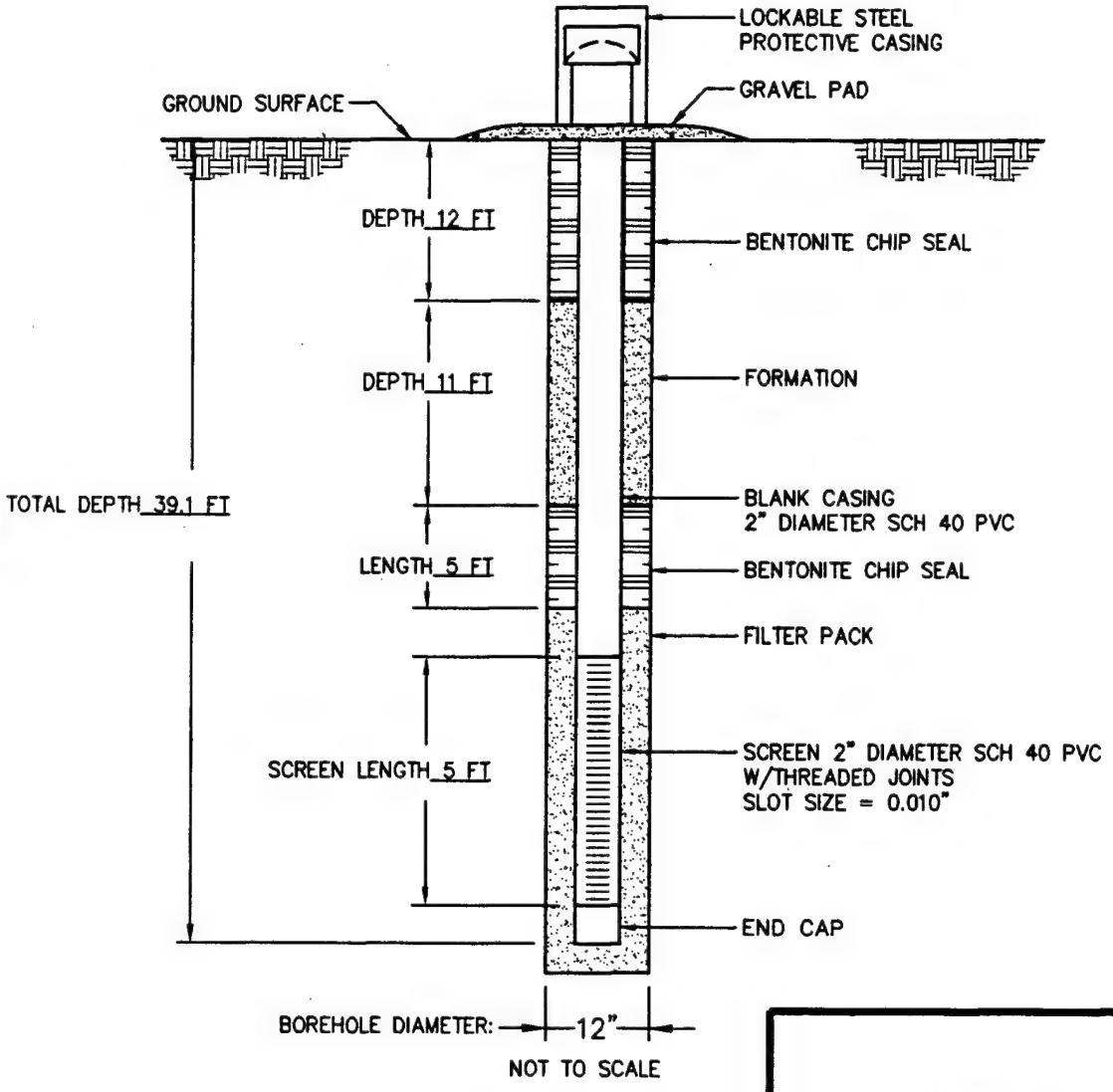
MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -1B
JOB NUMBER 722450.11 INSTALLATION DATE 9/14/94 LOCATION FT-001
DATUM ELEVATION 62.98 FEET ABOVE MLLW GROUND SURFACE ELEVATION 60.49 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 12 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 14.95 FEET BELOW DATUM.
TOTAL WELL DEPTH 39.98 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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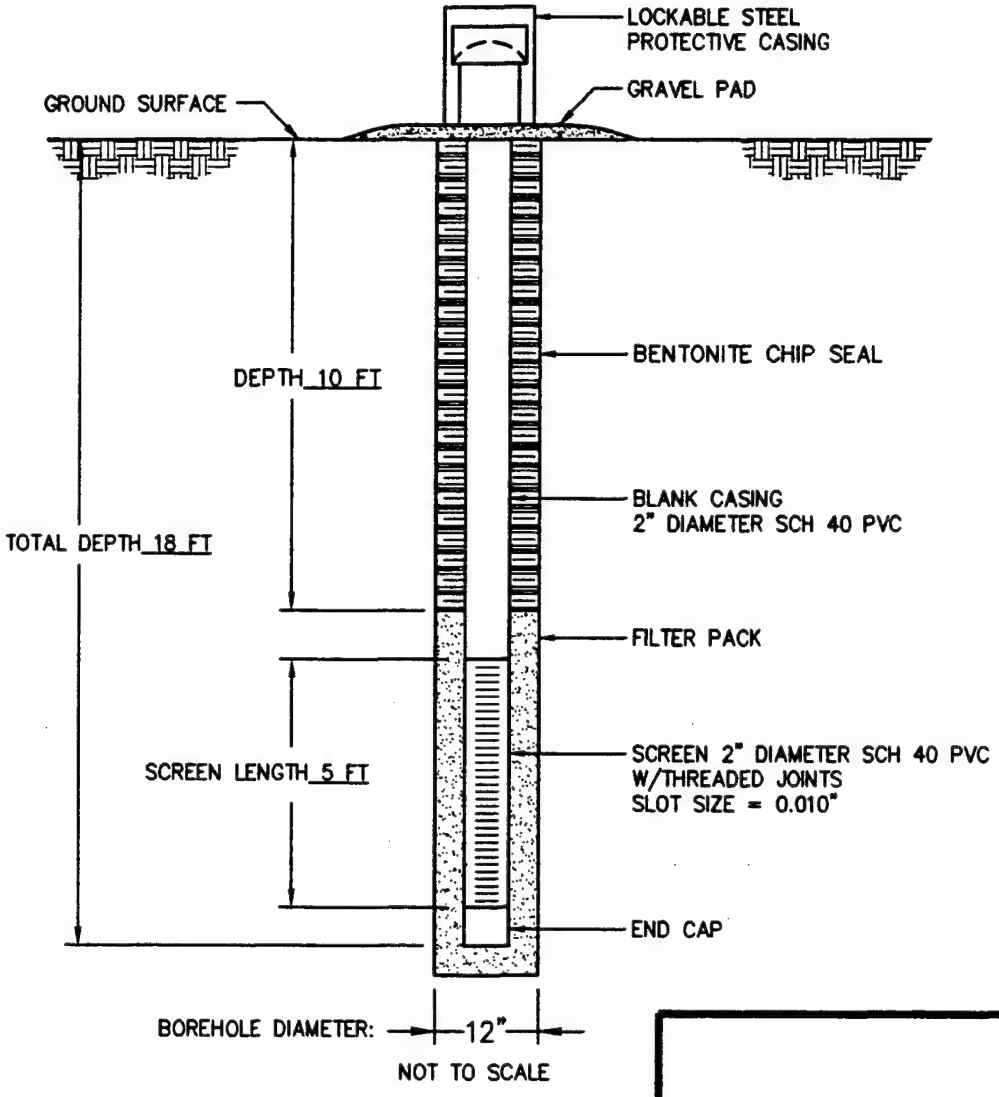
MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -2A
JOB NUMBER 722450.11 INSTALLATION DATE 9/13/94 LOCATION FT-001
DATUM ELEVATION 63.80 FEET ABOVE MLLW GROUND SURFACE ELEVATION 61.09 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 12 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 16.13 FEET BELOW DATUM.
TOTAL WELL DEPTH 20.0 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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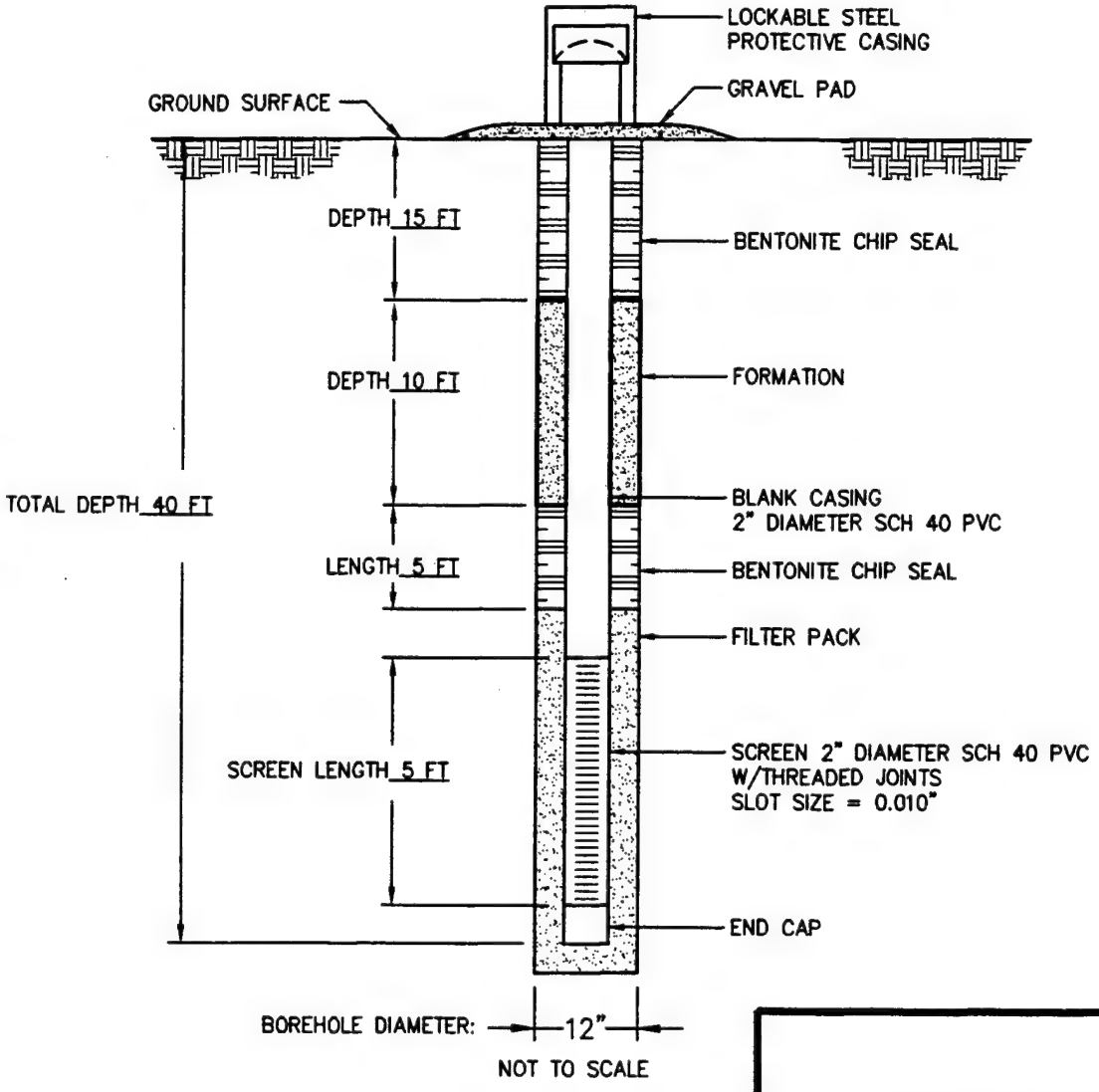
MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -2B
JOB NUMBER 722450.11 INSTALLATION DATE 9/15/94 LOCATION FT-001
DATUM ELEVATION 63.77 FEET ABOVE MLLW GROUND SURFACE ELEVATION 61.09 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 12 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 15.60 FEET BELOW DATUM.
TOTAL WELL DEPTH 40 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

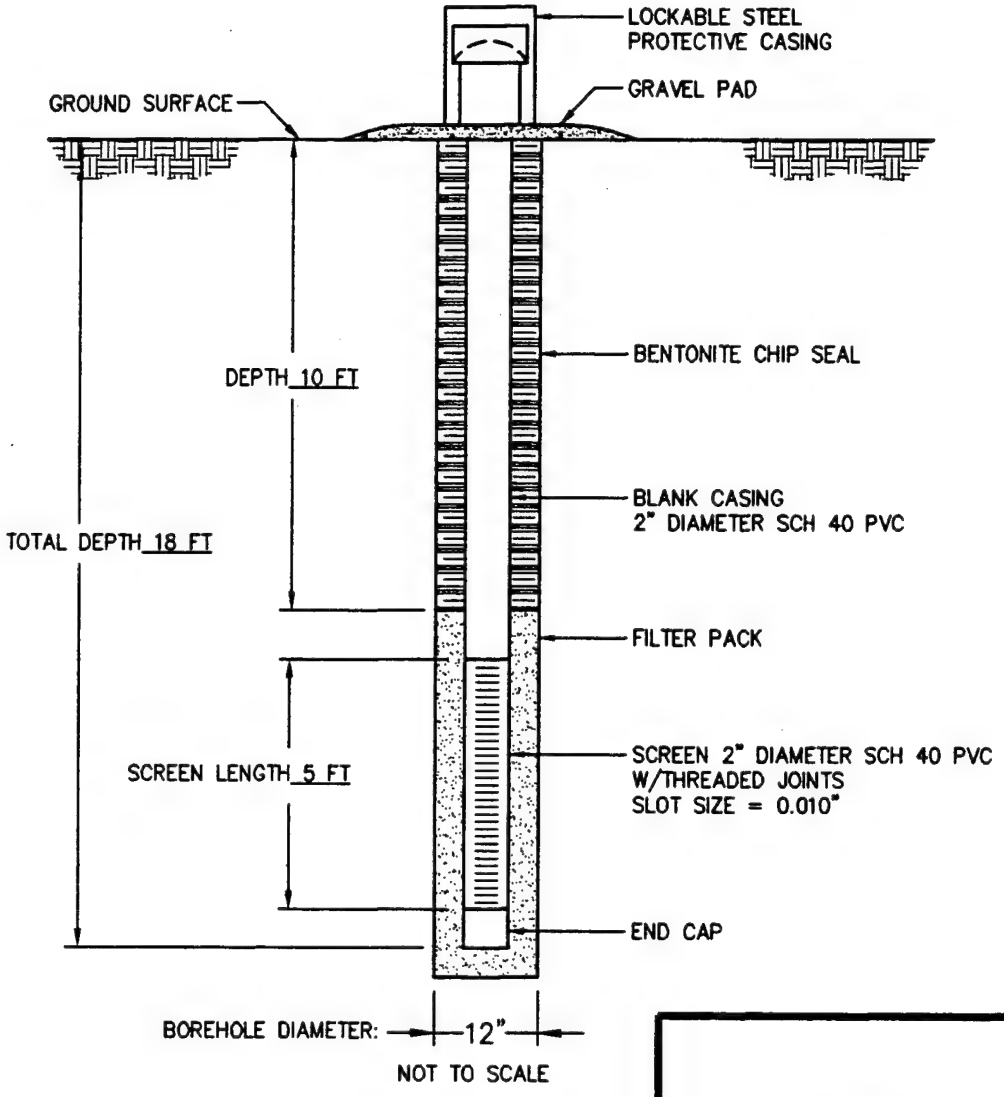
Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

L:\45011\DRAWINGS\WELLINST\96DN0373, 05/20/96 at 14:02

MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION — WELL NUMBER ESMW -3A
JOB NUMBER 722450.11 — INSTALLATION DATE 9/13/94 — LOCATION FT-001
DATUM ELEVATION 62.85 FEET ABOVE MLLW — GROUND SURFACE ELEVATION 60.49 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC — SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC — BOREHOLE DIAMETER 12 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND — ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER — DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 14.43 FEET BELOW DATUM.
TOTAL WELL DEPTH 19.95 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

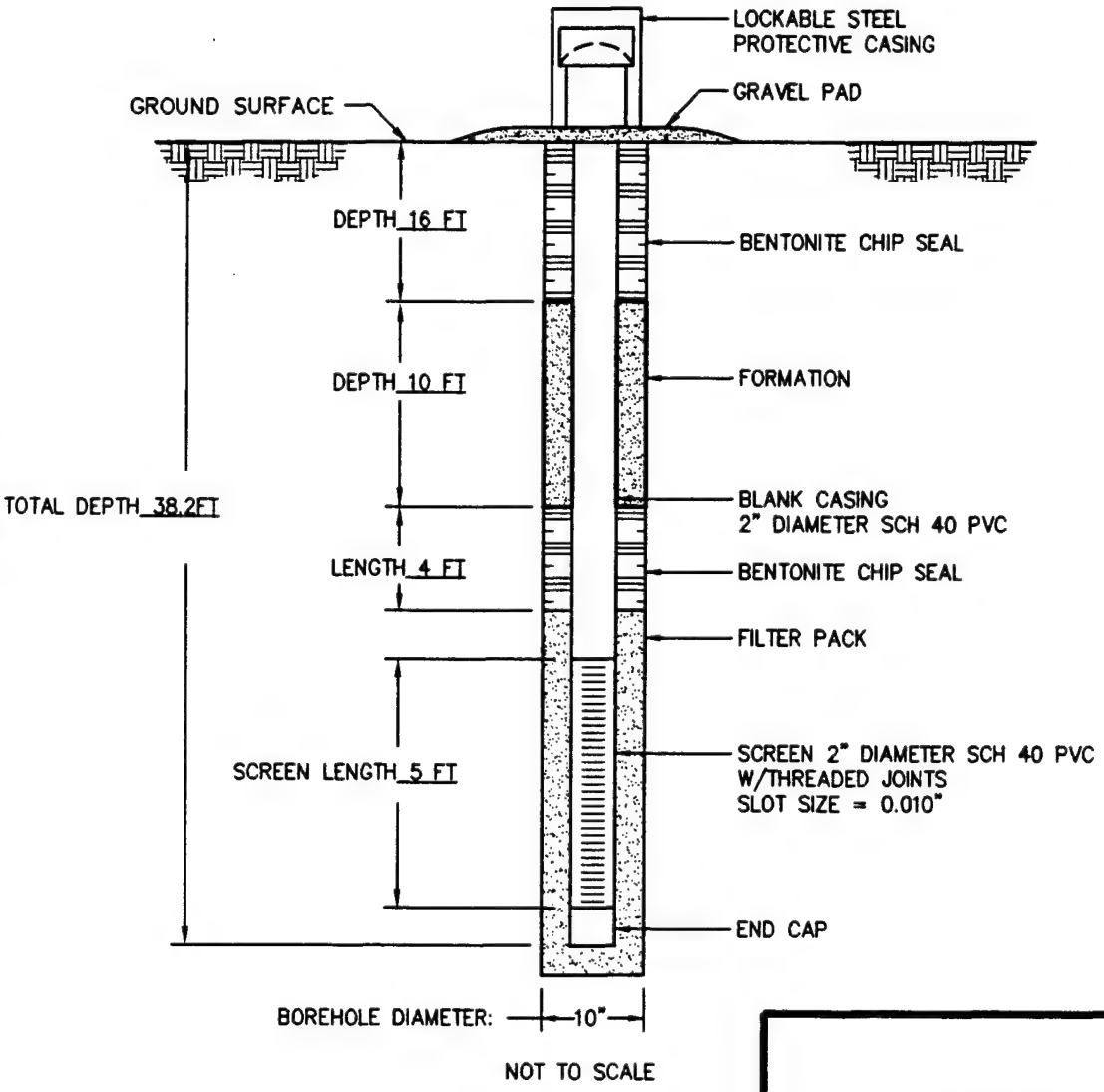
Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

L:\45011\DRAWINGS\WELLINST\96DN0374, 05/20/96 at 14:11

MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -3B
JOB NUMBER 722450.11 INSTALLATION DATE 9/15/94 LOCATION FT-001
DATUM ELEVATION 63.41 FEET ABOVE MLLW GROUND SURFACE ELEVATION 60.49 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 10 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 14.81 FEET BELOW DATUM.
TOTAL WELL DEPTH 41.39 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

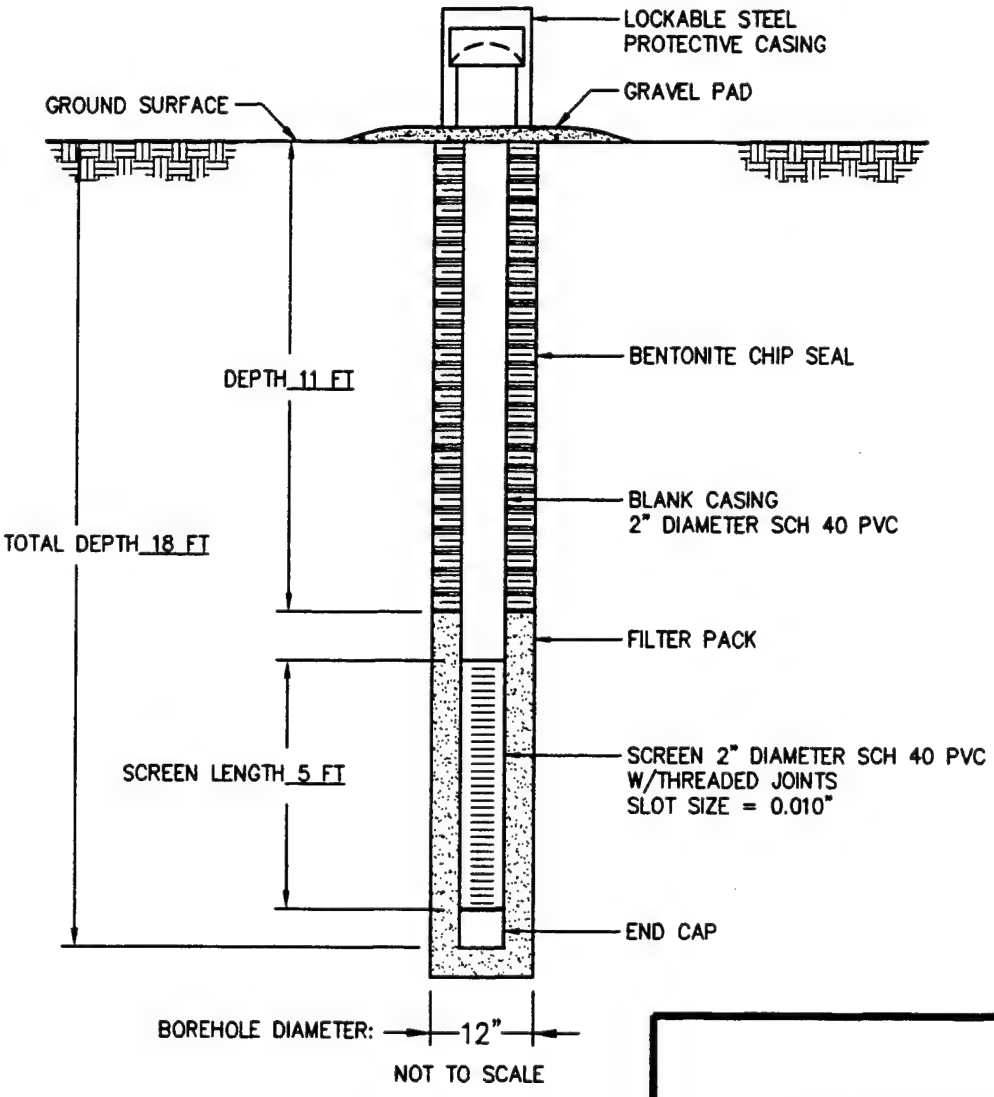
Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

L:\45011\DRAWINGS\WELLINST\96DN0375, 05/20/96 at 14:16

MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -4A
JOB NUMBER 722450.11 INSTALLATION DATE 9/12/94 LOCATION FT-001
DATUM ELEVATION 63.71 FEET ABOVE MLLW GROUND SURFACE ELEVATION 60.99 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 12 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 15.95 FEET BELOW DATUM.
TOTAL WELL DEPTH 21.45 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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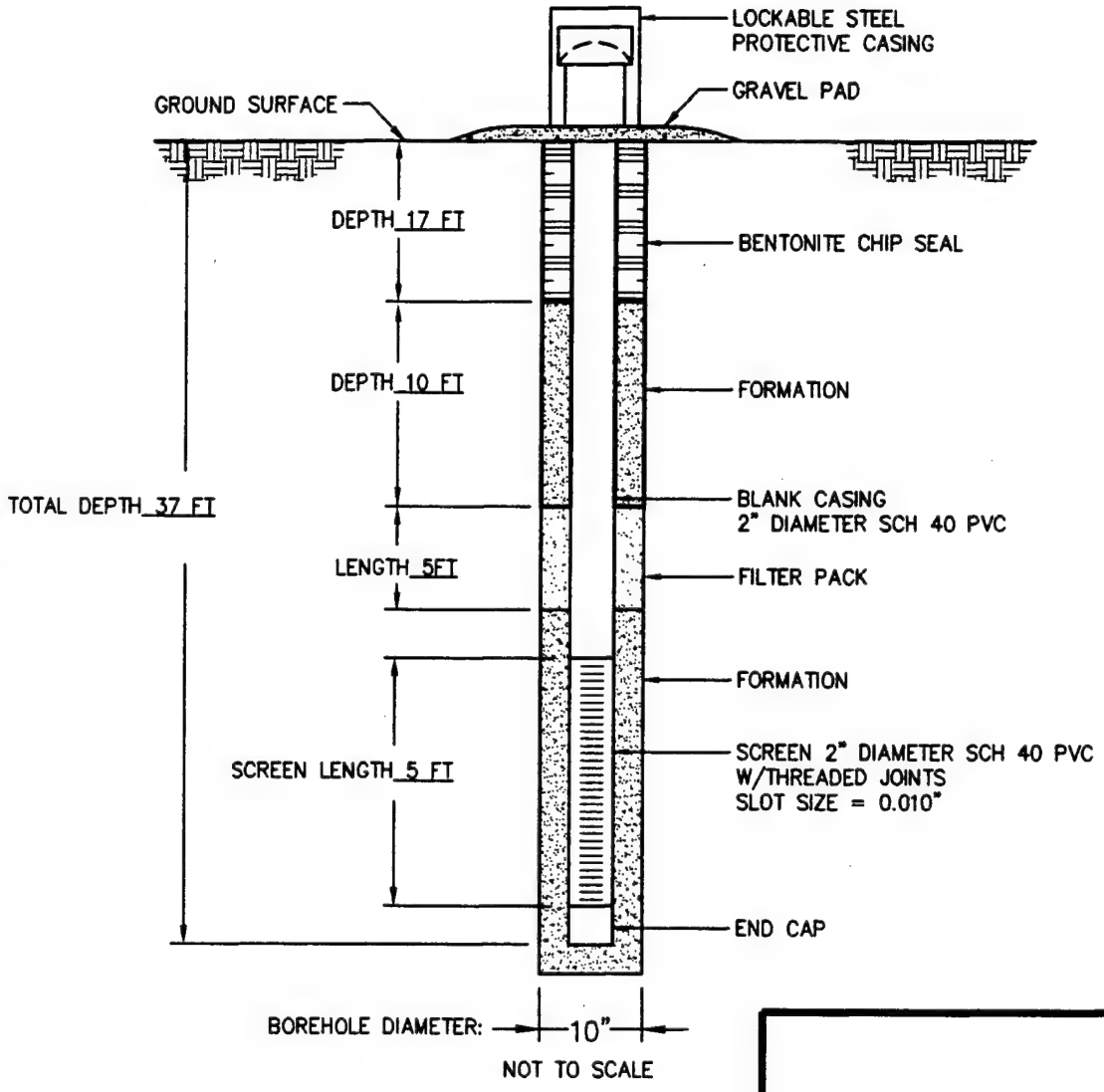
MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -4B
JOB NUMBER 722450.11 INSTALLATION DATE 9/15/94 LOCATION FT-001
DATUM ELEVATION 63.64 FEET ABOVE MLLW GROUND SURFACE ELEVATION 60.99 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 10 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 14.82 FEET BELOW DATUM.
TOTAL WELL DEPTH 37 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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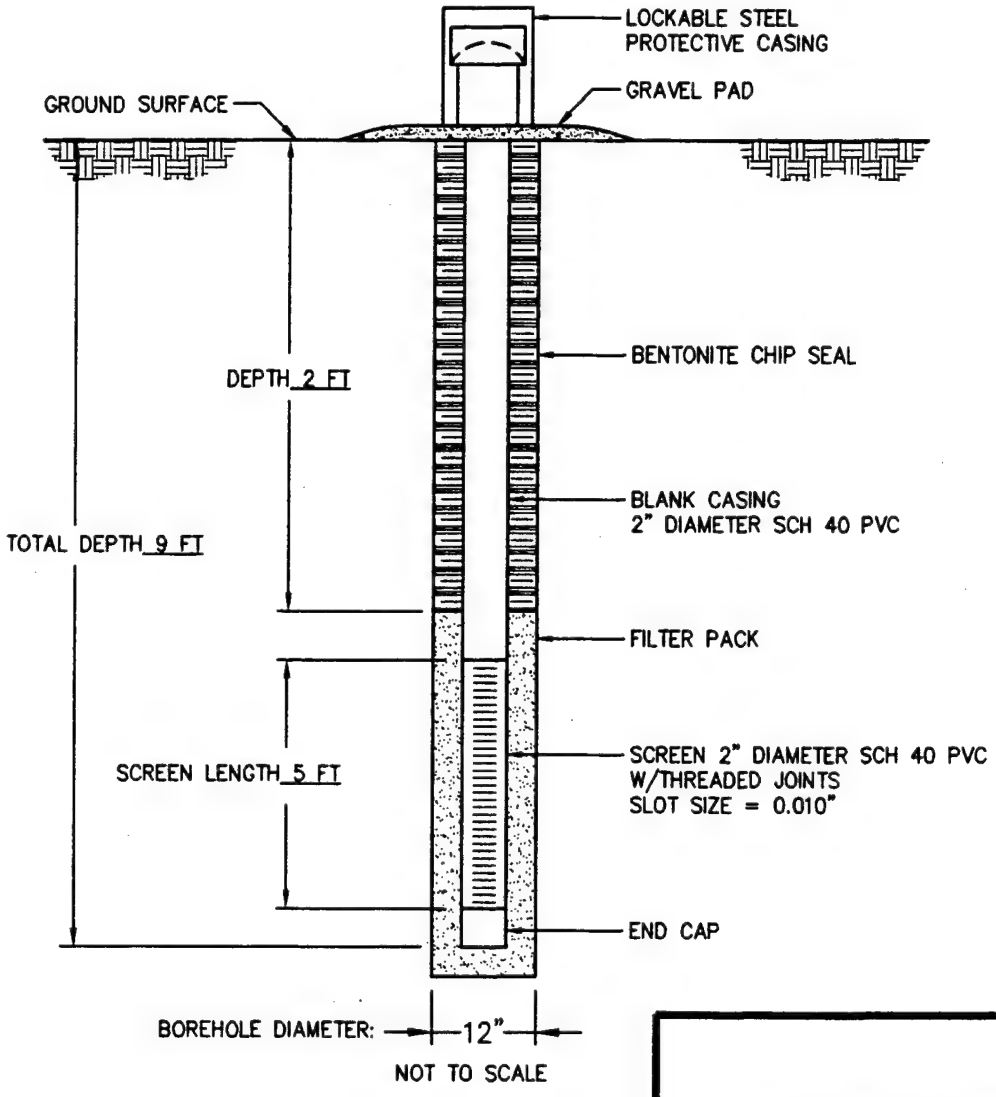
MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -5A
JOB NUMBER 722450.11 INSTALLATION DATE 9/12/94 LOCATION FT-001
DATUM ELEVATION 54.57 FEET ABOVE MLLW GROUND SURFACE ELEVATION 51.89 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 12 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 5.3 FEET BELOW DATUM.
TOTAL WELL DEPTH 9.3 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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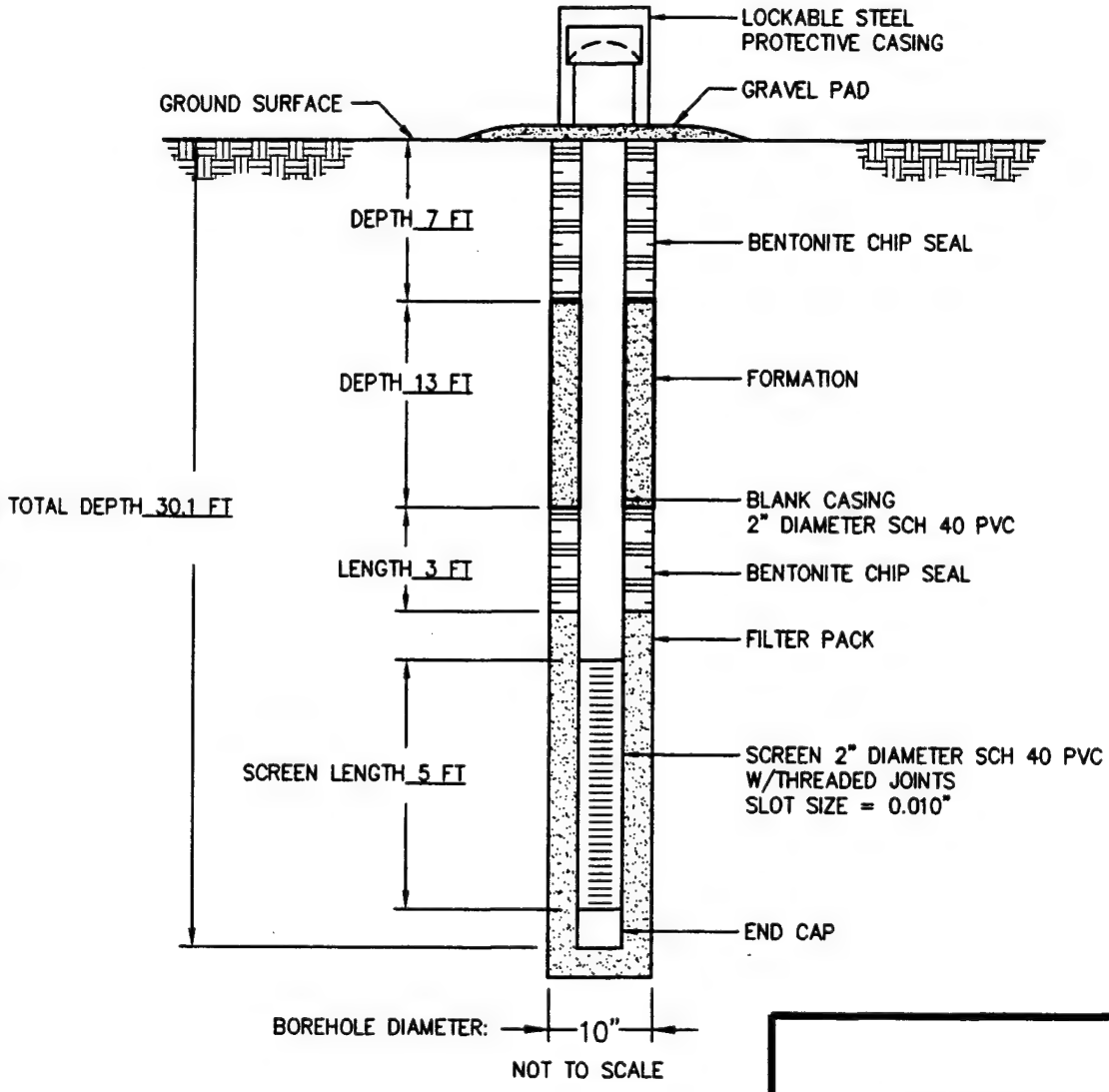
MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION — WELL NUMBER ESMW -5B
JOB NUMBER 722450.11 — INSTALLATION DATE 9/19/94 — LOCATION FT-001
DATUM ELEVATION 55.02 FEET ABOVE MLLW — GROUND SURFACE ELEVATION 51.89 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC — SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC — BOREHOLE DIAMETER 10 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND — ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER — DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 7.10 FEET BELOW DATUM.
TOTAL WELL DEPTH 29.98 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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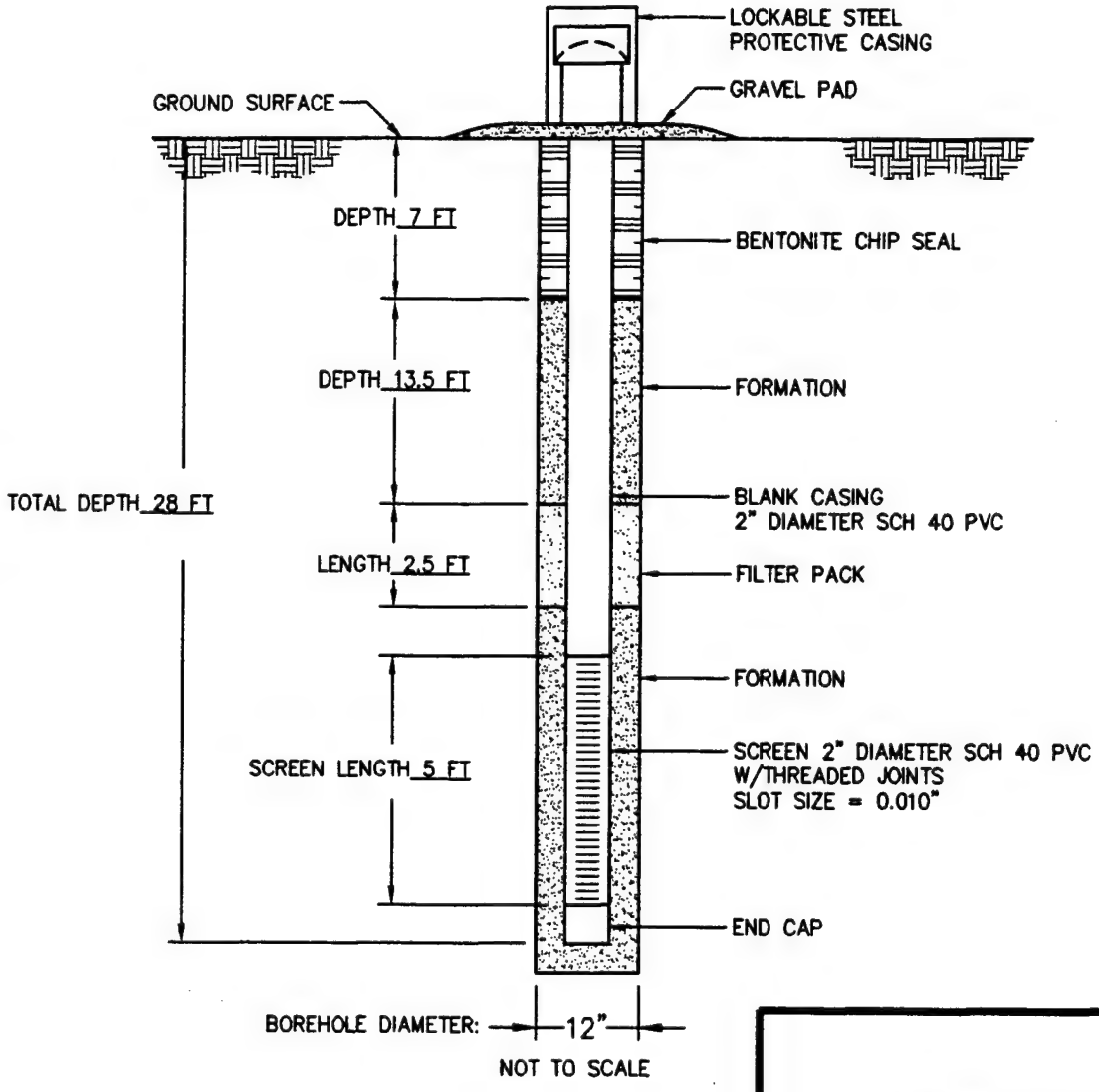
MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION — WELL NUMBER ESMW -6B
JOB NUMBER 722450.11 — INSTALLATION DATE 9/17/94 — LOCATION FT-001
DATUM ELEVATION 55.70 FEET ABOVE MLLW — GROUND SURFACE ELEVATION 52.99 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC — SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC — BOREHOLE DIAMETER 12 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND — ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER — DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 7.81 FEET BELOW DATUM.
TOTAL WELL DEPTH 29.7 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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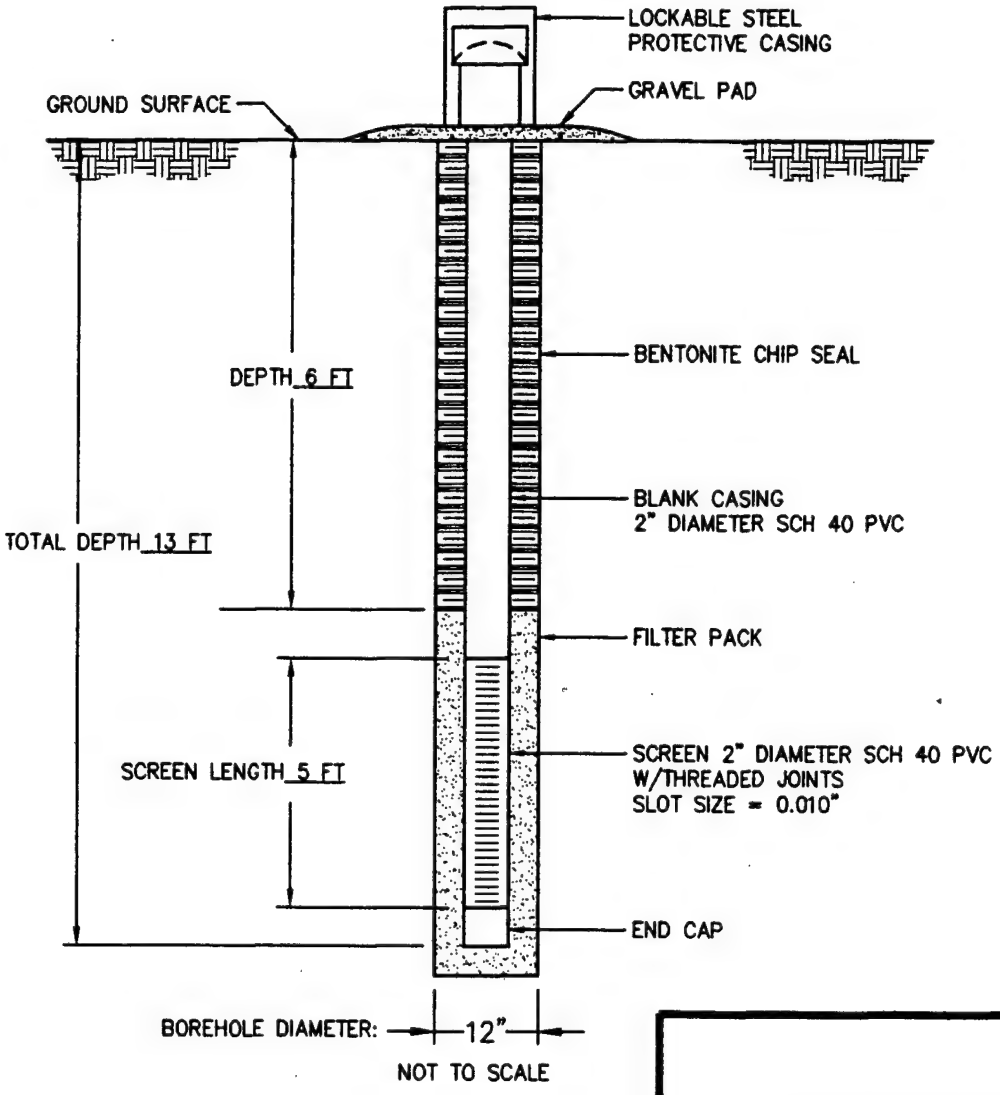
MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -7A
JOB NUMBER 722450.11 INSTALLATION DATE 9/11/94 LOCATION FT-001
DATUM ELEVATION 60.15 FEET ABOVE MLLW GROUND SURFACE ELEVATION 57.09 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 12 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 12.28 FEET BELOW DATUM.
TOTAL WELL DEPTH 13 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

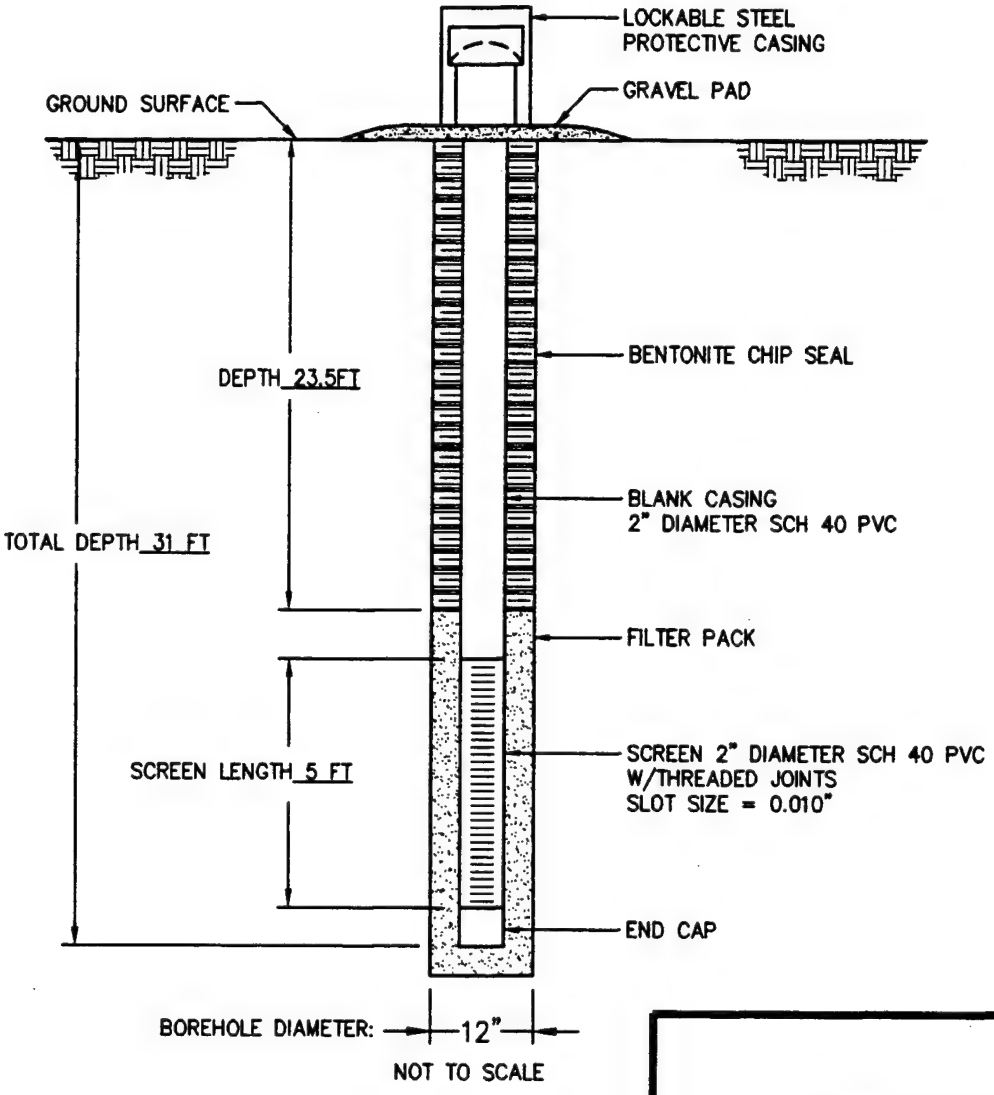
Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

L:\45011\DRAWINGS\WELLINST\96DN0381, 05/20/96 at 15:20

MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -7B
JOB NUMBER 722450.11 INSTALLATION DATE 9/12/94 LOCATION FT-001
DATUM ELEVATION 59.69 FEET ABOVE MLLW GROUND SURFACE ELEVATION 56.89 FT MLLW
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 12 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 11.83 FEET BELOW DATUM.
TOTAL WELL DEPTH 31 FEET BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Fire Training Area 1 (FT01)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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SURVEY RESULTS

Note on Survey Coordinates for Site FT01:

A discrepancy exists in the benchmark elevation at benchmark "B6" that was used to reference the site survey for Site FT01. Coastal Surveyors of Naknek, Alaska (the company contracted to perform the site survey by Parsons ES) used an elevation of 57.7 ft to reference the site survey. According to Ralph Mancusso of Coastal Surveyors, this elevation was supplied by the Air Force. According to Tom Sloan of the US Army Corps of Engineers in Anchorage, benchmark B6 has a reference elevation of 44.19 ft mllw that was established in 1962 by the USGS. To be consistent with surface elevations used in previous figures and tables as part of RI/FS work at King Salmon Airport, the elevation survey coordinates were referenced to a benchmark elevation of 44.19 ft. Therefore, 13.51 feet were subtracted from all water table elevations given by Coastal Surveyors in Tables 2.1 and 3.1 of this TS to transform them into elevations consistent with previous survey results.

FILE: 9431.TXT

WELLS- FIRE TRAINING AREA

PT#	EASTING	NORTHING	ELEV.	DESCRIPTOR
[illegible]	757712.8707	1711666.519	71.86	MONSPK
[illegible]	758613.2578	1712354.032	70.94	MONSPK
[illegible]	[illegible]9204.2187	1712349.631	73.73	MONSPK
[illegible]	[illegible]8642.6653	1712114.584	68.18	MONSPK
8	758891.8415	1712188.001	80.35	WELL435
10	758891.7343	1712187.968	78.0	GND-435
11	758907.8473	1712017.498	70.6	GND-ESMW7A
13	758908.7163	1712017.224	73.66	WELL-ESMW7A
15	758904.8247	1712015.643	70.4	GND-ESMW7B
16	758905.0954	1712015.557	73.20	WELL-ESMW7B
17	758675.0694	1712123.954	70.7	GND-MW653
18	758675.3053	1712124.135	73.51	WELL-MW653
19	758755.6252	1712181.657	72.0	BLDCOR
20	758736.4694	1712170.573	72.1	BLDCOR
21	758727.5468	1712185.741	72.8	BLDCOR
22	758707.4173	1712238.654	73.0	BLDCOR
23	758702.6258	1712235.748	73.0	BLDCOR
24	758689.9236	1712257.146	72.2	BLDCOR
25	758680.1221	1712251.524	72.2	BLDCOR
26	758657.2031	1712290.742	72.1	BLDCOR
27	758956.4743	1712396.325	77.22	WELL-ESMW4A
28	758966.3826	1712392.516	77.15	WELL-ES4MWB
29	758961.9389	1712393.939	74.5	GND-ES4MW
30	758968.6811	1712308.413	65.4	GND-ESMW5
31	758965.664	1712311.774	68.08	WELL-ESMW5A
32	758971.8217	1712306.067	68.53	WELL-ESMW5B
[illegible]	758995.419	1712299.688	65.8	TEST-PIT460A
[illegible]	[illegible]9101.8096	1712229.509	66.5	GND-ESMW6B
36	[illegible]9102.0613	1712228.833	69.21	WELL-ESMW6B
38	759091.1047	1712306.791	74.6	GND-ESMW2
39	759087.8114	1712308.502	77.31	WELL-ESMW2A
40	759095.5406	1712305.339	77.28	WELL-ESMW2B
41	759251.2945	1712288.313	76.36	WELL-ESMW3A
42	759261.3175	1712288.393	76.92	WELL-ESMW3B
43	759255.1043	1712287.696	74.0	GND-ESMW3
44	759313.4091	1712529.829	72.7	GND-MW94
45	759313.8078	1712530.146	74.78	— WELL-MW94
46	759302.6595	1712695.637	74.97	WELL-MW93
47	759304.3174	1712694.623	73.0	GND-MW93
48	759074.629	1712579.694	77.4	GND-MW92
49	759074.6562	1712583.056	78.56	CONC-MW92 (3' x 3' Conc. Slab)
50	759074.082	1712583.481	79.05	WELL-MW92
51	759106.081	1712440.717	74.67	WELL-MW95
52	759107.1917	1712441.382	72.7	GND-MW95
53	759182.966	1712464.846	74.0	GND-ESMW1
54	759184.2697	1712465.449	76.40	— WELL-ESMW1A
55	759181.177	1712465.034	76.49	WELL-ESMW1B
56	759120.565	1712371.457	74.4	TEST-PIT ESSB
58	759023.1122	1712227.063	75.58	WELL-460B
59	759023.8328	1712227.437	72.7	GND-460B
60	759240.5138	1712216.921	67.07	WELL-462C
[illegible]	759240.9489	1712217.112	65.6	GND-462C
7	[illegible]966.5626	1714189.673	57.70	USGSBC 'B6' RECORD CORDS.
714	[illegible]55165.97	1712600.17		USGSBC 'B2' RECORD CORDS.
715	757352.78	1711753.54	65.47	USGSBC 'A2' MEAS. CORDS.
716	756971.7625	1711605.192		R-W CL INT

SLUG TEST RESULTS

```
ESMW-1A
compny
PARSONS ENGINEERING SCIENCE
projno
722450.11
client
AFCEE
locsit
KING SALMON, ALASKA
tstdat
9-26-94
obswel
ESMW -1A
slugt1
0.878
0.166
0.833
slugt2
40
5
12.183
tsdata
0.03    0.878    1
0.06    0.54    1
0.09    0.321    1
0.12    0.202    1
0.15    0.118    1
0.18    0.084    1
0.21    0.05    1
0.24    0.033    1
0.27    0.025    1
0.3    0.025    1
0.33    0.016    1
0.36    0.008    1
0.39    0.008    1
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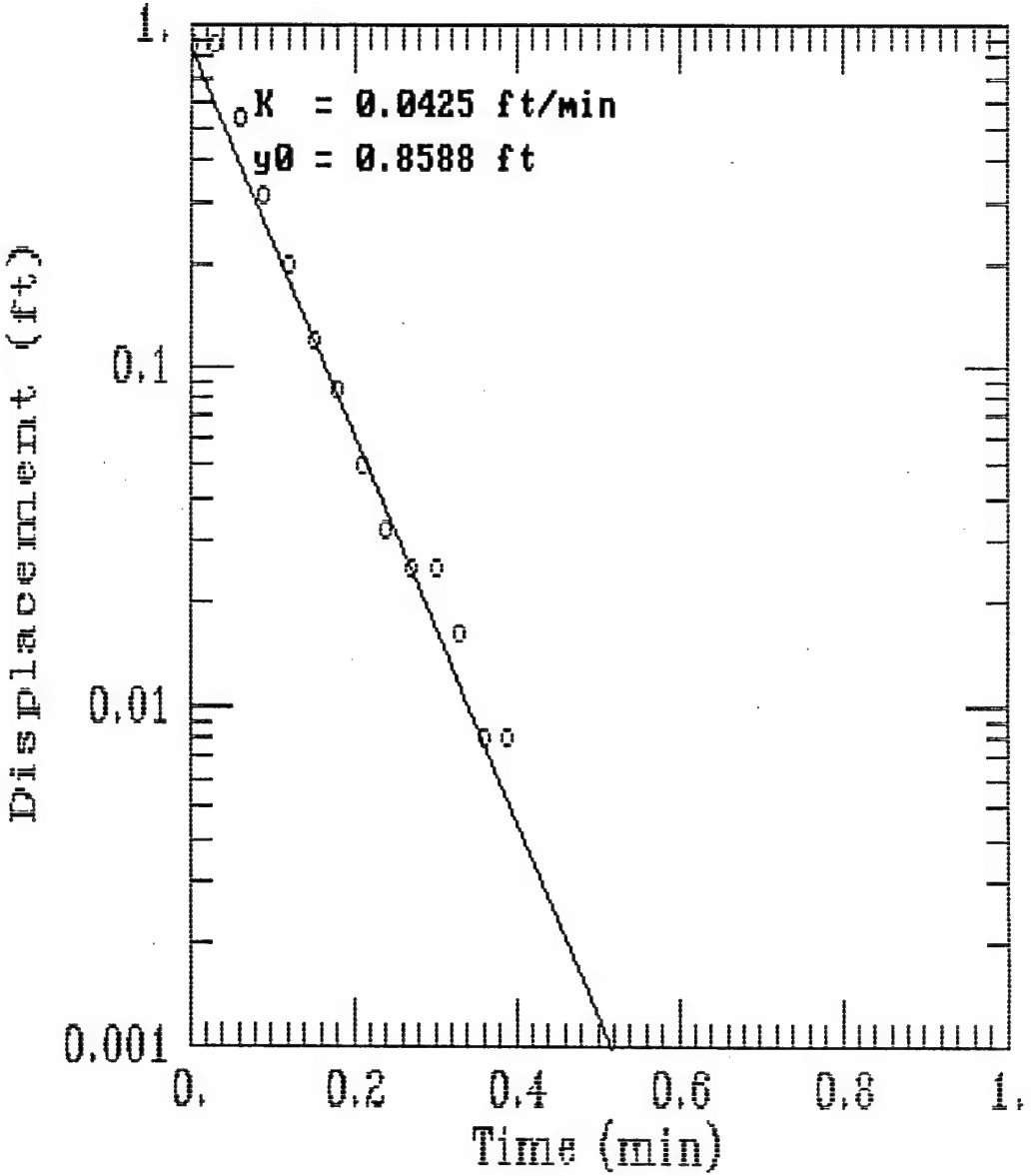
ESMW-1A


K = 0.0425 ft/min
y0 = 0.8588 ft
1.
0.1
0.01
0.001
0.
0.2
0.4
0.6
0.8
1.
Displacement (ft)
Time (min)

```
ESMW-1A
compny
PARSONS ENGINEERING SCIENCE
projno
722450.11
client
AFCEE
locsit
KING SALMON, ALASKA
tstdat
9-26-94
obswel
ESMW-1A
slugt1
0.008
0.0833
0.416
slugt2
40
5
12.141
tsdata
0.03    0.008    1
0.06    0.067    1
0.09    0.059    1
0.12    1.428    1
0.15    0.735    1
0.18    0.405    1
0.21    0.219    1
0.24    0.135    1
0.27    0.067    1
0.3    0.034    1
0.33    0.017    1
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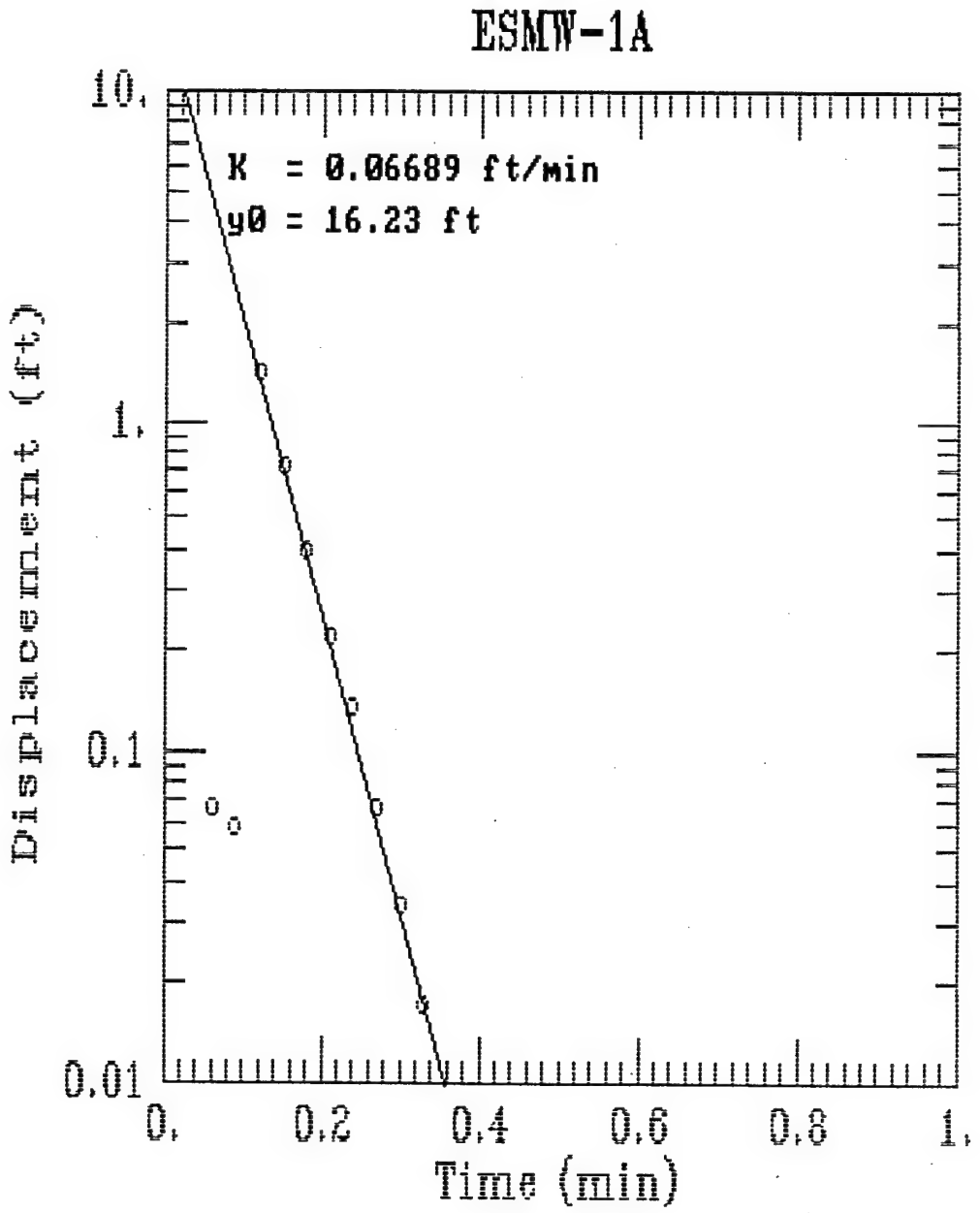
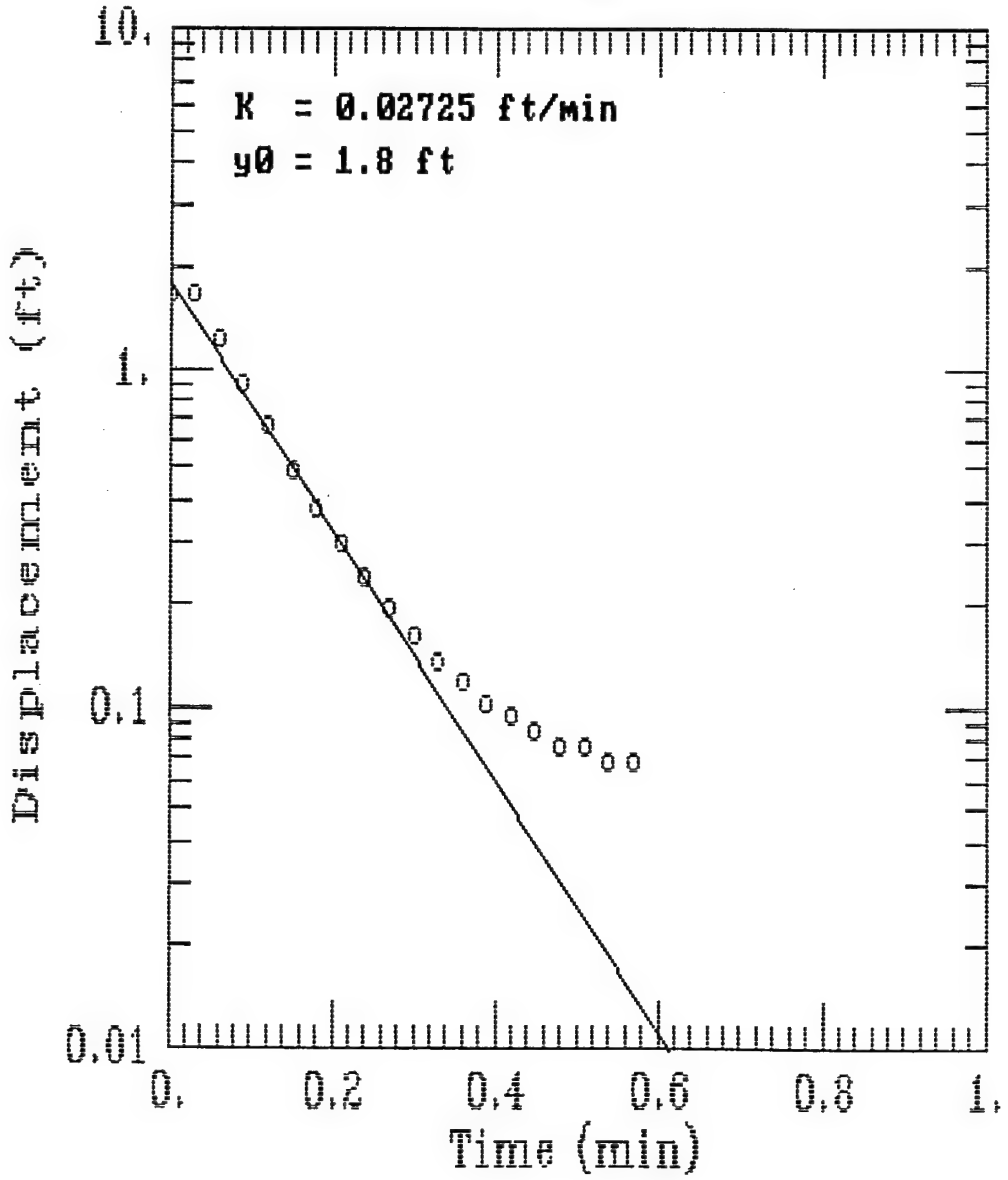

ESMW-1A
K = 0.06689 ft/min
y0 = 16.23 ft
Displacement (ft)
10.
1.
0.1
0.01
0.
0.2
0.4
0.6
0.8
1.
Time (min)

ESMW-2A
compny
PARSONS ENGINEERING SCIENCE
projno
722450.11
client
AFCEE
locsit
KING SALMON, ALASKA
tstdat
9-26-94
obswel
ESMW-2A
slugt1
1.6725
0.0833
0.416
slugt2
35
5
10.84
tsdata

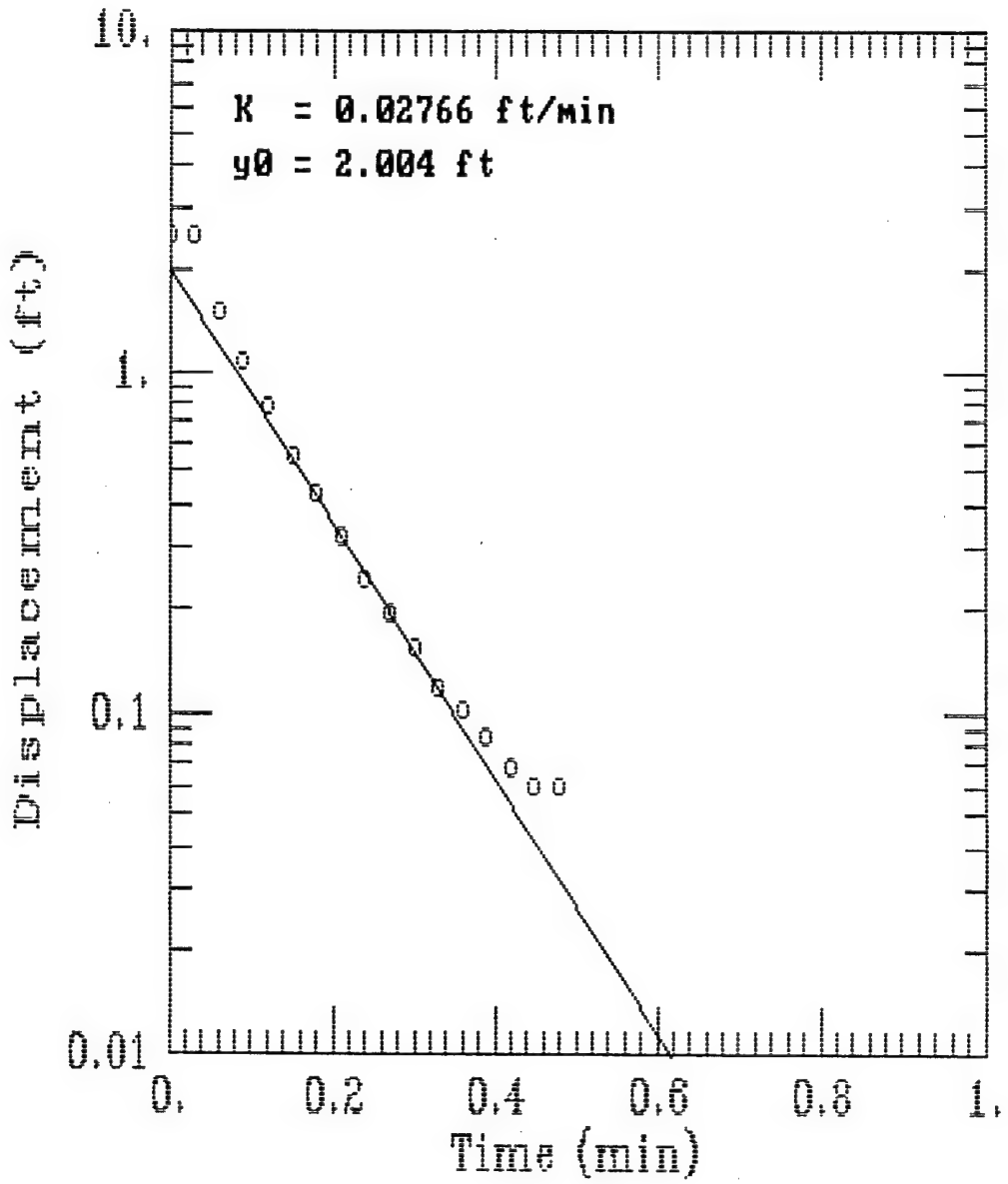
0.03	1.6725	1
0.06	1.2163	1
0.09	0.8952	1
0.12	0.668	1
0.15	0.49	1
0.18	0.38	1
0.21	0.304	1
0.24	0.237	1
0.27	0.194	1
0.3	0.161	1
0.33	0.135	1
0.36	0.118	1
0.39	0.101	1
0.42	0.093	1
0.45	0.085	1
0.48	0.076	1
0.51	0.076	1
0.54	0.068	1
0.57	0.068	1

ESMW-2A


K = 0.02725 ft/min
y0 = 1.8 ft
Displacement (ft)
10.
1.
0.1
0.01
0.
0.2
0.4
0.6
0.8
1.
Time (min)

```
ESMW-2A
compny
PARSONS ENGINEERING SCIENCE
projno
722450.11
client
AFCEE
locsit
KING SALMON, ALASKA
tstdat
9-26-94
obswel
ESMW-2A
slugt1
2.501
0.0833
0.4166
slugt2
35
5
10.832
tsdata
0.03    2.501    1
0.06    1.4955    1
0.09    1.0731    1
0.12    0.795    1
0.15    0.567    1
0.18    0.431    1
0.21    0.322    1
0.24    0.245    1
0.27    0.195    1
0.3    0.153    1
0.33    0.119    1
0.36    0.102    1
0.39    0.085    1
0.42    0.068    1
0.45    0.06    1
0.48    0.06    1
```

ESMW-2A


K = 0.02766 ft/min
y0 = 2.004 ft
10.
1.
0.1
0.01
Displacement (ft)
0.
0.2
0.4
0.6
0.8
1.
Time (min)

APPENDIX B

PREVIOUS ANALYTICAL DATA

AND UNPUBLISHED INFORMATION

America North/EMCON, Inc.

Environmental Consulting/Natural Resources Management

WELL DETAILS

PROJECT NUMBER 5210.025.00

PROJECT NAME K.S. FT01 French Drain

LOCATION FT01

INSTALLATION DATE 10-17-94

WELL OWNER CODE: USAF

WELL COMPLETION METHOD: _____

BORING/WELL NO. FT01FD8

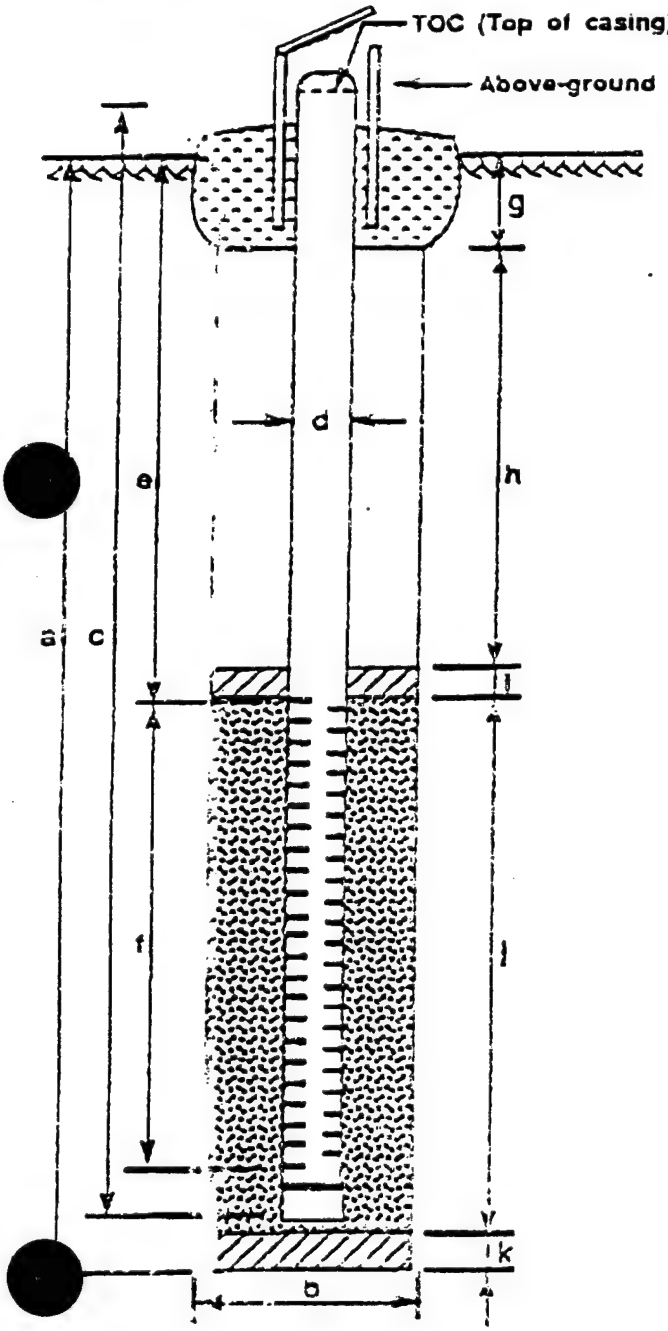
TOP OF CASING ELEV.(MPE): _____

GROUND SURFACE ELEV. _____

DATUM _____

GEOHYDROLOGIC ZONE:

WELL TYPE: _____



EXPLORATORY BORING

a. Total depth 13 ft.

b. Diameter 2" in.

Drilling method Hollow Stem Auger

WELL CONSTRUCTION

c. Total casing length 15 ft.

Material PVC sch 40

d. Inside Diameter 2" in.

e. Depth to top screen 3 ft.

f. Screen length 10 ft.

Screen interval from 13 to 3 ft. b.g.s

Screen type prepack slotted

Screen Slot size .010 in.

g. Surface seal: 2-0 ft.

Seal material bentonite chips

h. Backfill _____ ft.

Backfill material _____

i. Seal _____ ft.

Seal material _____

j. Filter pack 2-0 ft.

Pack material 10/20 silica Sand

k. Bottom seal _____ ft.

Seal material _____

Form prepared by Jim Daigle

Date 10-17-94

America North/EMCON, Inc.

Environmental Consulting/Natural Resources Management

WELL DETAILS

PROJECT NUMBER 5210.025.00 BORING/WELL NO. FTO1FD9

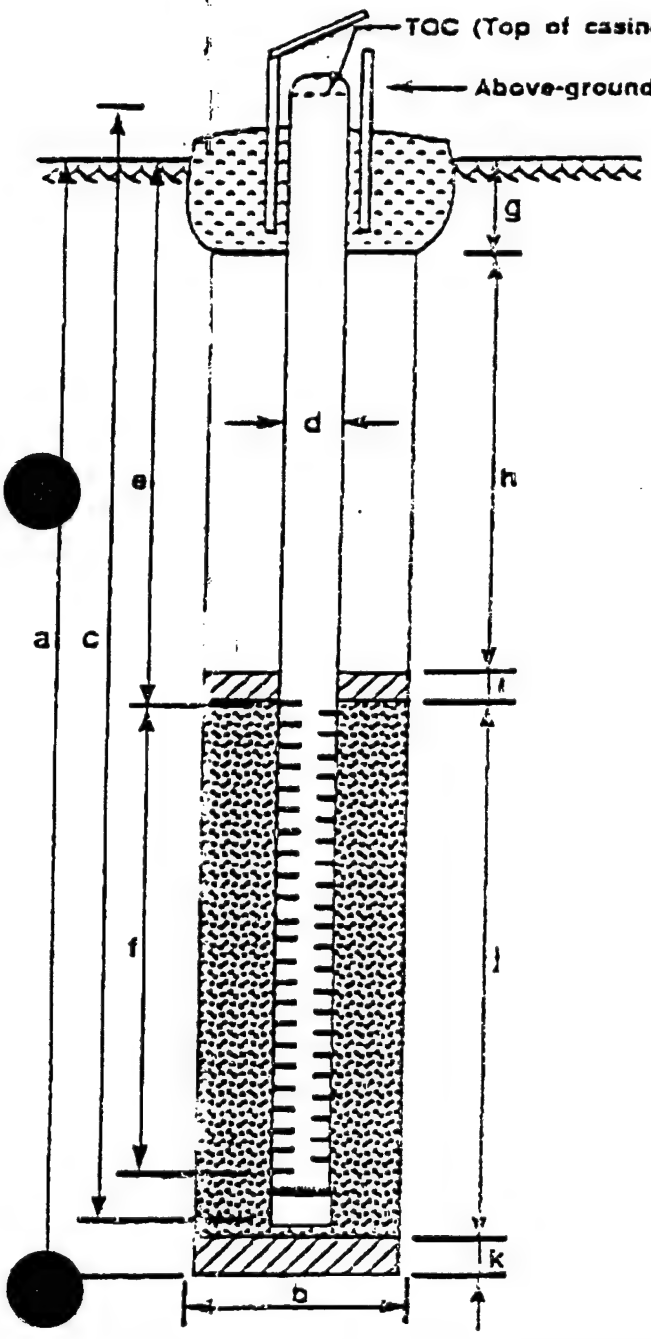
PROJECT NAME K.S. FTO1 French Drain TOP OF CASING ELEV.(MPE): ____

LOCATION FTO1 GROUND SURFACE ELEV. ____

INSTALLATION DATE 10-17-94 DATUM ____

WELL OWNER CODE: (USAF) GEOHYDROLOGIC ZONE:

WELL COMPLETION METHOD: ____ WELL TYPE: ____



EXPLORATORY BORING

a. Total depth 13 ft.

b. Diameter 2" in.

Drilling method Hollow Stem Auger

WELL CONSTRUCTION

c. Total casing length 15 ft.

Material PVC sch 40

d. Inside Diameter 2" in.

e. Depth to top screen 3 ft.

f. Screen length 10 ft.

Screen interval from 13 to 3 ft b.g.s

Screen type prepack slotted

Screen Slot size .010 in.

g. Surface seal; 2-0 ft.

Seal material Bentonite chips

h. Backfill ____ ft.

Backfill material ____

i. Seal ____ ft.

Seal material ____

j. Filter pack 13-2 ft.

Pack material 20/40 silica sand

k. Bottom seal ____ ft.

Seal material ____

Form prepared by Tim Voigt

Date 10-17-94

EMCON Alaska, Inc.

FIELD LOG OF BORING

Sheet 1 Of 2

Project: K.S. FT01 French Drain	Boring Depth (ft): 50
Project #: 5210.025.00	Begin Depth: End Depth: 50
Project Mgr: J. Dodd	Construction Method: HSA
Logged By: J. Dodd	Geohydrologic Flow Class:
Edited By:	Geologic Completion Zone:
Boring #: FT01ED5 SB	Borehole Diameter (in):
Drilling Contractor: Johnson Well Drilling	Water Depth (ft): Date:
Drill Rig Type: Acker	Time:
Driller's Name: D.F.	Surface Elev: Datum:
Sampling Method:	North Coord:
Hammer Wt:	East Coord:
Started/Time:	Inside Air Force Boundary? (Yes) No
Completed/Time: 1000 Date: 10-12-94	Location Type:
Site Name: Fire Training Area #1	Backfill Time: Date:
Site X-ref: Site ID: FT01	By:
Location Description:	

PID/HEADSPACE	BLOWS/6 IN	FEET DRIVEN	PT RECOVERED	STRAT ORDER	ASTM CODE	SAMPLE INTERVAL	DEPTH IN FT
					SM		1
					SP		2
							3
							4
							5

Location (continued)

Lithologic Description & Sample Information:

0-2' (SM) Silty Sand Lt Brown 7.5YR 6/4
moist, Loose, no odor, no staining

2'-5' (SP) Sand - 10YR 5/2 yellowish
Brown Sandy, moist, Loose, no odor
no staining

Comments:

BORING.XLS

Revised 3/31/94

EMCON Alaska, Inc.

FIELD LOG OF BORING

Sheet 2 Of 6

Project # 5216.025.00 Boring # FT01FD5SB

PID/ DSPACE	BLOWS/6 IN	FEET DRIVEN	FT RECOVERED	STRAT ORDER	ASTM CODE	SAMP INTERVAL	DEPTH IN FT	Lithologic Description & Sample Information:
							6	5–6' SAME AS ABOVE
								6'–10' Sand Lt Brownish gray 10YR 6/2
					SP	▼	7	wet at 7' BGS, Strong petroleum like odor
								staining,
							8	PID headspace = 579
								Soil sample take at this depth 7' BGS
							9	Sample # FT01FD5SB
				2			10	
								10–15 (SP) Sand Lt. Brownish gray
							1	10YR 6/2, ~~wet~~ Very fine Sand
								85% very fine Sand, 5% medium sand
							2	10% silt, wet, Loose
					SP			
							3	
							4	
							15	
								15'–20' Same As Above

Comments:

EMCON Alaska, Inc.

FIELD LOG OF BORING

Sheet 3 Of 6

Project # 5210.025.00 Boring # FT01FD55B

PID/HNU DISPACE	BLOWS/6 IN	FEET DRIVEN	FT RECOVERED	STRAT ORDER	ASTM CODE	SAMP INTERVAL	DEPTH IN FT	Lithologic Description & Sample Information:
							6	
							7	
					SP	SP		
							8	
							9	
							20	
				2				20 - 25 Same As Above
							1	
							2	
					SP			
							3	
							4	
							25	25'-30' Same As Above

Comments:

EMCON Alaska, Inc.

FIELD LOG OF BORING

Sheet 4 of 6

Project # 5210.025.00 Boring # FTO1 FD550

PID/HEADSPACE	BLOWS/6 IN	FEET DRIVEN	FT RECOVERED	STRAT ORDER	ASTM CODE	SAMP INTERVAL	DEPTH IN FT	Lithologic Description & Sample Information:
							6	
							7	
				SP			8	
							9	
							30	
			2					30-35 SAME AS Above
							1	
							2	
				SP			3	
							4	
							35	
								35-40 Same As Above

Comments:

BORING.XLS

Revised 3/31/94

EMCON Alaska, Inc. **FIELD LOG OF BORING** Sheet 5 Of 6

Project # 5210.025.00 Boring # 1FT01FD55B

PID/HEADSPACE	BLOWS/6 IN	FEET DRIVEN	FT RECOVERED	STRAT ORDER	ASTM CODE	SAMP INTERVAL	DEPTH IN FT	Lithologic Description & Sample Information:
							6	
							7	
				SP			8	
							9	
			2				40	40'-45' Same As Above
							1	
							2	
				SP			3	
							4	
							45	45'-50' SAME AS ABOVE

Comments:

BORING.XLS

Revised 3/31/94

EMCON Alaska, Inc.

FIELD LOG OF BORING

Sheet 6 Of 6

Project # 5210.025 00 Boring # FT01FD5 SB

PID/HDSPACE	BLOWS/6 IN	FEET DRIVEN	FT RECOVERED	STRAT ORDER	ASTM CODE	SAMP INTERVAL	DEPTH IN FT	Lithologic Description & Sample Information:
							6	
							7	
				2	SP		8	
							9	
							50	Boring terminated at 50' BGS
							1	no clay layer found at this depth & above
							2	
							3	
							4	
							5	

Comments:

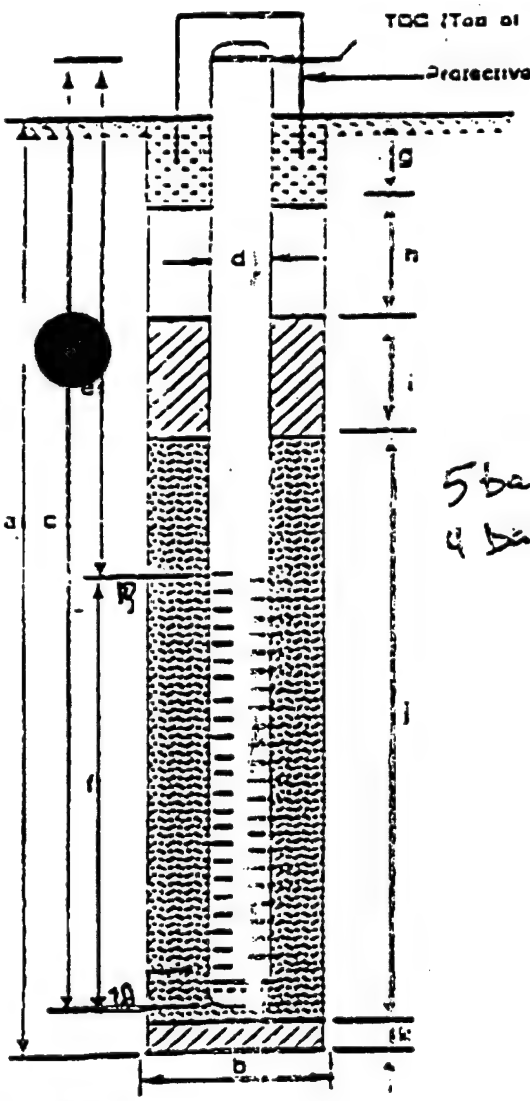
EMCON Alaska, Inc.
201 East 56th • Suite 300 • Anchorage, Alaska 99518-1241 • (907) 562-3452 • Fax (907) 563-2814

WELL DETAILS - ABOVE GROUND COMPLETION

(see back for note descriptions)

PROJECT #: 5210-007.00 T5A
PROJECT NAME: King Salmon RI ES VER.1
BORING/WELL #: FT01163
INSTALLATION DATE: 5/8/94
WELL OWNER[1]: USAF
WELL COMPLETION METHOD[2]: GS
SITE NAME: Rapcon / Fire Training Area #1

TOP OF CASING ELEV.: 58.03
GROUND SURFACE ELEV.: 55.05
NORTH COORD[3]: 1711909.9707
EAST COORD[3]: 1898103.7.115
GEOHYDROLOGIC ZONE[4]: W
WELL TYPE[5]: MW
SOLE SOURCE AQUIFER[6]:



5 bags sand
4 bags bentonite

EXPLORATORY BORING

a. Borehole depth: 20 ft.
b. Borehole diameter: 8 in.
Drilling method: HS

WELL CONSTRUCTION

c. Screen Casing, riser length: 22.5 ft.
Material: PVC Sch
d. Inside diameter: 2 in.
e. Depth to top screen (bgs): 9.5 ft.
f. Screen length: 10 ft.
Perforated interval from 9.5 to 19.5 ft. (bgs)
Perforation type: Slot
Perforation size: .08 in.
Percent open area: %
g. Surface seal: 7 ft. (bgs)
Seal material: bentonite chips
h. Backfill: 7 ft.
Backfill material: bentonite chips
i. Seal: 7 ft.
Seal depth (base of seal; bgs): 7.5 ft.
Seal material: bentonite chips
j. Filter pack (length): 12.5 ft.
Pack material: 10/20 Silica Sand
k. Bottom seal: .5 ft.
Seal material: cuttings
l. Stickup: 3' ft.
(above ground surface)

Form prepared by: Scott Bie
Date: 5/8/94

Remarks:

EMCON Alaska, Inc.

FIELD LOG OF BORING

Sheet 2 Of 3

Project # 5210-007.00 Boring # FT01653

PID SPACE	BLOWS/6 IN	FEET DRIVEN	FT RECOVERED	STRAT ORDER	ASTM CODE	SAMP INTERVAL	DEPTH IN FT	Lithologic Description & Sample Information:
~~5~~	5					X	6	~~5~~ FT01653SB(5-6.5) @ 1548
~~6~~	6				SM	X		SM (ML) silty sand ~~sandy silt~~ 3/2 10YR very dark
							7	grayish brown, 30% silt, 70% fine
								grained sand, damp, loose to medium
							8	dense, slight odor
							9	
								odor in cutting @ 10'
							10	
						X		FT01653(~~5-6.~~ 10-11.5) @ 1557 ~75% recovery
	10					X		(SP) silty sand, 5/1 10YR reddish gray,
	13					X	11	90% fine to medium grain sand, ~~5%~~ 5% silt
							12	~~5%~~ 3% coarse grained sand (subrounded
								to subangular, 2% gravel (subrounded),
							13	moist, medium dense, ~~st~~ odor
							14	
							15	WATER @ 15 7.5 ppm in borehole
	10					X		drillers report strong odor

Comments:

ING.XLS

Revised 3/31/94

EMCON Alaska, Inc. **FIELD LOG OF BORING** Sheet 3 Of 3

Project # 5210-007.00 Boring # FT01653

HEADSPACE	BLOWS/6 IN	FEET DRIVEN	FT RECOVERED	STRAT ORDER	ASTM CODE	SAMP INTERVAL	DEPTH IN FT	Lithologic Description & Sample Information:
	10					X	16	FT01653SB(15-16.5)@ 1604
46.8 ppm	18					X		5' Sand, 5/1 10YR Gray
							17	<5% silt, 5% coarse grained sand, 2% gravel (subrounded to subangular), 88% fine to medium grained sand, wet, medium dense, moderate odor
							18	
							19	PID @ 1616 = 144.8 ppm
								13 gallons of water added to borehole to flush sand from auger bottom
							20	→ hole completed @ 20' ~1610
							1	
							2	* Auger came up w/ brown foam on it @ 10+ feet when pulled up during backfill
							3	
							4	
							5	

Comments:

EMCON Alaska, Inc.
4701 Business Park Boulevard • Suite 36 • Anchorage, Alaska 99503-7166 • (907) 562-3452 • Fax (907) 563-2814

FAX TRANSMITTAL

TO: Tod Herrington DATE: 4-23-96

FROM: Jim Daigle TIME: 3:00

Number of Pages 2 (Including Cover Page)

If you have received this communication in error, please notify us at the telephone number listed above.

Sender Note: Complete if applicable.

CLIENT: _____ Project/Task #: 10842626

PHONE #: _____ FAX #: 1-303-831-8208

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COMMENTS:

This is from the Summary section of the Eco Risk thought it might be useful.

Jim

ORIGINAL TO FOLLOW: ____ ORIGINAL WILL NOT FOLLOW: ____ BROADCAST: ____

ANY QUESTIONS REGARDING THIS TRANSMISSION, PLEASE CALL THE NUMBER LISTED ABOVE

White Alice Communications (OT010). No surface water is present at this site. Small, plant-eating (herbivorous), ground-feeding mammals are potentially at risk from ingestion of plants that have accumulated polychlorinated biphenyls (PCB)-1260 from soil; one HI exceeded 1.0 at 7.2. Plants are potentially at risk from exposure to petroleum-related chemicals in soil, on the basis of exceedances of estimated SRBCs.

The results for Water Table System 4 are described below:

Lower Naknek (SS012L). Terrestrial wildlife species are not expected to be at risk from exposure to chemicals in soil; HIs for the terrestrial food chain were less than 1.0. However, insectivorous and piscivorous birds and mammals from the aquatic food chain are potentially at risk from ingestion of food containing diesel components; HIs that exceeded 1.0 ranged from 1.5 to 4,200. Similarly, fish and other aquatic organisms are potentially at risk from exposure to petroleum-related chemicals in surface water, due to exceedances of WRBCs.

Upper Naknek (SS012U). In the terrestrial food chain, small-bodied, ground-feeding, insectivorous birds and mammals are potentially at risk from ingestion of soil contaminated with polycyclic aromatic hydrocarbons (PAHs); HIs that exceeded 1.0 ranged from 1.3 to 25. In the aquatic food chain, small insectivorous and piscivorous birds may be at risk to diesel components (primarily aliphatics) that bioaccumulate in fish and other aquatic organisms eaten by wildlife; HIs that exceeded 1.0 ranged from 140 to 730. Also, fish and other aquatic organisms are potentially at risk from exposure to the aliphatic components of diesel in surface water, on the basis of exceedances of WRBCs. The risks are greatest for small-bodied species with small home ranges that may live exclusively at the site.

The results for Water Table System 5 are described below:

Fire Training Area (Red Fox Creek, FT001). In the terrestrial food chain, small-bodied, ground-feeding birds and mammals are potentially at risk from ingestion of food and soil contaminated with dioxins and petroleum hydrocarbons, especially aliphatics from both gasoline-range organics (GRO) and diesel-range organics (DRO); HIs that exceeded 1.0 range from 4.7 to 14. In the aquatic food chain, small insectivorous and piscivorous birds are potentially at risk from ingesting food containing gasoline and diesel components (primarily aliphatics); HIs that exceeded 1.0 range from 36 to 600. Also, fish and other aquatic organisms are potentially at risk from exposure to the aliphatic components of DRO and GRO in surface water due to exceedances of WRBCs. Plants are potentially at risk from exposure to petroleum-related chemicals in soil on the basis of exceedances of SRBCs. The estimated area of impacted soil and wetland at the Fire Training Area and Red Fox Creek are smaller than the typical home range of most indicator species. Therefore, the greatest risks are expected for small-bodied species with small home ranges that could possibly live exclusively at the sites.

EMCON Alaska, Inc.

4701 Business Park Boulevard • Suite 36 • Anchorage, Alaska 99503-7166 • (907) 562-3452 • Fax (907) 563-2313

FAX TRANSMITTAL

TO: Tod Harrington DATE: 4-23-96

FROM: Jim Doig TIME: 9:18

Number of Pages 6 (Including Cover Page)

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COMMENTS:

Tod

This is info I found in the ecological Risk Assessment

Do you need info from the Human Health Risk A.?

Let me know if you need anything else

Jim

ORIGINAL TO FOLLOW: ____ ORIGINAL WILL NOT FOLLOW: ____ BROADCAST: ____

ANY QUESTIONS REGARDING THIS TRANSMISSION, PLEASE CALL THE NUMBER LISTED ABOVE

ECO Risk

calculations are provided in Appendix E and the results are summarized in Tables 6-1 (terrestrial food chain) and 6-2 (aquatic food chain).

Most birds and mammals at KSA range over areas larger than the impacted sites to meet their daily food and water requirements. Therefore, more realistic HI estimates were made by considering the home range sizes of the indicator species. It was assumed that wildlife feed and drink equally over all areas in their home range. If the area of an impacted site represents only a fraction of an animal's home range, it was assumed that only a portion of ingested food, water, soil, and sediment was impacted. For example, if the area of impacted soil was 20 percent of the home range size of an indicator species, the total HI for the species at the site would be reduced by multiplying by 0.2. Table 6-3 presents estimates of the home range sizes of the indicator species and the ratios of site areas to animal home range sizes. If the ratio for one species was greater than 1, it was assumed that the indicator species feeds and drinks only from the impacted site. The risk characterization results are discussed by site and by food chain, with emphasis on HIs greater than 1.0. Home range estimates were taken from the Wildlife Exposure Factors Handbook (USEPA, 1993). These estimates were confirmed by research at Alaska Department of Fish and Game (ADF&G).

Although results of risk characterizations are often discussed for specific indicator species, indicator species were chosen to represent exposure conditions shared by a number of wildlife species. Therefore, risk results for particular indicator species should be interpreted as representing risks for wildlife with exposure conditions (e.g., diet) similar to the indicator species (see Appendix B). For example, risk characterizations for the American robin should be interpreted as representing risks for small, ground-feeding, insectivorous birds in the terrestrial food chain, and risk results for the American dipper should be interpreted as representing risks for small birds that primarily forage on aquatic invertebrates such as many shorebirds.

6.2 Aquatic Organisms

Risks for fish and other aquatic organisms were evaluated by comparing the EPC for each chemical in surface water (see Table 1-2) with the WQC or the derived WRBC for surface water, if available (see Table 6-4). Because the WQCs and WRBCs are estimates of screening concentrations that are thresholds for adverse ecological effects, it is inferred that fish and other aquatic organisms will be at risk if COPC concentrations in surface waters are above these criteria. It should be noted that the WRBCs are often based on only a few studies, and great uncertainty is associated with WRBC estimates.

ECO Risk

6.3 Risk to Plants

Risks to plants were evaluated using an approach similar to that used for fish and other aquatic organisms. Table 6-5 provides a comparison of the toxicity values for plants with 95% UCLs of chemicals detected in surface and root-zone soil. Limited plant toxicity data were available.

6.4 Fire Training Area No. 1 (FT001)

In the terrestrial food chain, small-bodied, ground-feeding birds and mammals are potentially at risk from ingestion of food and soil contaminated with dioxins and petroleum hydrocarbons, especially aliphatics from both GRO and DRO (Table 6-1 and Appendix E). In the aquatic food chain, small insectivorous and piscivorous birds are potentially at risk from ingesting food containing gasoline and diesel components (primarily aliphatics) (Table 6-2 and Appendix E). Also, fish and other aquatic organisms are potentially at risk from exposure to the aliphatic components of DRO and GRO in surface water that were estimated using fractionation methods and fate and transport modeling (Table 6-4). Comparisons of soil concentrations with the available SRBCs indicate that plants are potentially at risk from petroleum-related chemicals in soil (see Table 6-5).

The estimated area of impacted soil and wetland at the Fire Training Area and Red Fox Creek are smaller than the typical home range of most indicator species. Therefore, the greatest risks are expected for small-bodied species with small home ranges that could possibly live exclusively at the site.

6.4.1 Terrestrial Wildlife

Four indicator species have final HIs that exceeded 1.0: the winter wren (4.7), American robin (6.2), meadow vole (9.4), and pygmy shrew (10.4) (Table 6-1). Small-bodied, insectivorous birds are potentially at risk from ingestion of food and soil containing dioxins (42 percent, HpCDD and OCDD) and petroleum hydrocarbons (54 percent, primarily the aliphatic components of DRO, GRO and xylenes) (Appendix E). Small-bodied, herbivorous mammals are potentially at risk from incidental ingestion of soil containing dioxins (54 percent) and aliphatic components of DRO and GRO (33 percent), while small-bodied, insectivorous mammals are potentially at risk from incidental ingestion of soil containing dioxins (98 percent) (Appendix E). The site is smaller than the home ranges of most indicator species, and few individuals are expected to forage exclusively at the site. However, if it is assumed that terrestrial wildlife feed only from chemically-impacted areas, HIs exceeded 1.0 for all indicator species (see Table 6-1).

Eco Risk

6.4.2 Aquatic Wildlife

Three indicator species (birds) have final HIs greater than 1.0: the spotted sandpiper (600), American dipper (440), and belted kingfisher (36) (see Table 6-2). These small birds feed on aquatic invertebrates or small fish. Through fractionation, fate and transport modeling, and bioaccumulation modeling, several DRO and GRO surrogate chemicals are predicted to occur in aquatic invertebrates and fish at concentrations high enough to cause risks to insectivorous and piscivorous wildlife. Ingestion of food containing the aliphatic fraction of DRO (indicated by *n*-nonane) accounts for 92 to 94 percent of the total HIs for the above indicator species (Appendix E). The chemically-impacted area of Red Fox Creek is smaller than the home ranges of most aquatic indicator species, and piscivorous wildlife are expected to obtain only a portion of their diet from the site. However, if it is assumed that aquatic wildlife feed only from chemically-impacted areas, HIs exceeded 1.0 for all piscivorous birds and mammals (see Table 6-2).

6.4.3 Fish and Other Aquatic Organisms

Three petroleum surrogate chemicals are estimated to occur at waterborne concentrations high enough to pose potential risks to fish and other aquatic organisms in Red Fox Creek (see Table 6-4). DRO and GRO fractions of aliphatics and hexane were estimated by fate and transport modeling from the Fire Training Area to surface water; also, the aliphatic fraction of detected DRO was estimated as *n*-nonane; the WRBC for each of these compounds was 0.056 micrograms per liter (µg/L). Waterborne concentrations of aliphatics (9.5 µg/L), hexane (1.2 µg/L) and *n*-nonane (287 µg/L) exceeded this WRBC.

6.4.4 Plants

Plants are potentially at risk from petroleum-related chemicals in soil. Estimated EPCs of xylenes, toluene, and gasoline compounds in soil exceeded their respective SRBCs (see Table 6-5).

6.5 South Barrel Bluff (LF005)

No soil samples or modeled concentrations of chemicals in soil were available for this site; therefore, terrestrial wildlife were not evaluated. Insectivorous and piscivorous birds and mammals are potentially at risk from ingestion of food containing mercury and chemical constituents of diesel (Table 6-2 and Appendix E). Waterborne concentrations of diesel components (estimated through DRO fractionation) and mercury are predicted to bioaccumulate in invertebrates and small fish to levels that may cause risks to insectivorous and piscivorous wildlife. Also, fish and other aquatic organisms are potentially at risk from exposure to mercury and petroleum-related chemicals in surface

SENT BY: 4-23-96 ; 8:17AM ; EMCON ALASKA INC.→ 1303-831-5555;# 5/ 6

ECO Risk

Table C-1
King Salmon Airport
Bioaccumulation Concentrations
Site FT001 (Fire Training Area [Red Fox Creek])

Chemical	Bioaccumulation from Soil: Soil EPC C_s (a) (mg/kg)	Plant Uptake Factor PUF (b) (Unitless)	Plant EPC Plant Tissue Conc. C_{psoil} (c) (mg/kg)	Feed-to-Meat Transfer Factor FMTR (d) (Unitless)	Herb EPC Terrestrial Herbivore Conc. C_h (e) (mg/kg)	Bioaccumulation from Surface Water: Surface Water EPC C_w (f) mg/L	Fish 2 EPC: Trophic Level 2 Bioaccum. BAF_2 (g) Unitless	Fish 2 EPC: Level 2 Fish Conc. C_{a2} (h) mg/kg	Fish 3 EPC: Trophic Level 3 Bioaccum. BAF_3 (g) Unitless	Fish 3 EPC: Level 3 Fish Conc. C_{a3} (i) mg/kg	Bioaccumulation from Sediments: Sediment EPC C_{sed} (j) (mg/kg)	Plant Uptake Factor PUF (b) (Unitless)	Plant EPC Plant Tissue Conc. C_{psed} (k) (mg/kg)
Acetone						2.47E-03	1.22E+00	3.01E-03	1.22E+00	3.01E-03	2.71E-01		
Aliphatics	3.15E+03	1.79E+00	5.62E+03	7.33E-04	3.40E-01	9.56E-03	3.66E+03	3.50E+01	3.66E+03	3.50E+01	9.18E+00	1.79E+00	1.64E+01
Arsenic							1.20E+01		1.20E+01				
Barium													
Benzene							9.20E+01		9.20E+01		8.32E-03		
Benzo(a)anthracene	3.50E-01	4.82E-02	1.69E-02	2.32E-02	4.77E-05	5.77E-05	1.68E+05	9.71E+00	3.82E+05	2.21E+01		4.82E-02	
Benzo(a)pyrene	1.30E-01	7.82E-02	1.02E-02	6.54E-02	7.06E-05	2.11E-05	7.31E+05	1.54E+01	2.26E+06	4.76E+01		7.82E-02	
Benzo(b)fluoranthene		8.85E-02		6.24E-02								8.85E-02	
Benzo(k)fluoranthene		2.10E-02		6.54E-02								2.10E-02	
Bis(2-ethylhexyl)phthalate		1.36E+00		7.33E-03			3.49E+04		5.13E+04			1.36E+00	
Chlordane		8.25E-02		1.72E-02			5.74E+04		1.46E+06			8.25E-02	
Chloroform							4.40E+01		4.40E+01				
Chloromethane													
Chrysene	5.50E-01	1.23E-01	6.75E-02	2.27E-02	1.49E-04	9.05E-05	2.47E+05	2.24E+01	6.22E+05	5.63E+01		1.23E-01	
Cymene													
DDD		7.98E-02		5.56E-02								7.98E-02	
DDT		7.89E-01		1.30E-01			1.64E+06		4.00E+06			7.89E-01	
Di-n-butyl phthalate		1.81E-01		2.27E-02								1.81E-01	
Dichlorobenzene, 1,3-													
Dichloroethane, 1,1-							4.90E+01		4.90E+01				
Dichloroethane, 1,2-							2.70E+01		2.70E+01		2.15E-05		
Dichloroethene, cis-1,2-							9.08E+01		9.08E+01				
Dichloropropane, 1,2-													
Dichloropropene, 1,3-													
Dieldrin		6.51E-01		2.02E-03			1.48E+05		2.34E+05			6.51E-01	
Ethylbenzene							6.60E+02		6.60E+02		3.85E-03		
Fluoranthene	1.43E+01	1.35E-01	1.94E+00	4.52E-03	8.40E-04		3.90E+04		6.16E+04		1.38E+00	1.35E-01	1.87E-01
Fluorene	2.80E+02	4.95E-01	1.38E+02	8.42E-04	9.93E-03	4.58E-02	1.16E+04	5.30E+02	1.16E+04	5.30E+02		4.95E-01	

EC Risk

Table C-1
King Salmon Airport
Bioaccumulation Concentrations
Site FT001 (Fire Training Area [Red Fox Creek])

	Bioaccumulation from Soil					Bioaccumulation from Surface Water					Bioaccumulation from Sediments		
							Fish 2 EPC		Fish 3 EPC				
Chemical	Soil EPC C_s (a) (mg/kg)	Plant Uptake Factor PUF (b) (Unitless)	Plant EPC Plant Tissue Conc. C_{psoil} (c) (mg/kg)	Feed-to-Meat Transfer Factor FMTR (d) (Unitless)	Herb EPC Terrestrial Herbivore Conc. C_h (c) (mg/kg)	Surface Water EPC C_w (f) mg/L	Trophic Level 2 Bioaccum. BAF_2 (g) Unitless	Level 2 Fish Conc. C_{a2} (h) mg/kg	Trophic Level 3 Bioaccum. BAF_3 (g) Unitless	Level 3 Fish Conc. C_{a3} (i) mg/kg	Sediment EPC C_{sed} (j) (mg/kg)	Plant Uptake Factor PUF (b) (Unitless)	Plant EPC Plant Tissue Conc. C_{psed} (k) (mg/kg)
Heptachlor epoxide							3.53E+03		3.53E+03				
Hexane, n-	3.92E+02	1.79E+00	7.01E+02	7.33E-04	4.23E-02	1.19E-03	3.66E+03	4.35E+00	3.66E+03	4.35E+00	1.14E+00	1.79E+00	2.04E+00
HpCDD	4.10E-03	9.37E-01	3.84E-03	9.02E+00	2.89E-03		3.16E+05		3.16E+05		9.18E-06	9.37E-01	8.59E-06
Indeno(1,2,3-cd)pyrene		1.09E-01		2.16E-01								1.09E-01	
Isopropyl benzene							5.37E+03		5.37E+03				
Lead							1.84E+02		1.84E+02				
Mercury							1.12E+05		2.40E+05				
Methyl ethyl ketone							4.00E+00		4.00E+00				
Methylene chloride							1.20E+01		1.20E+01		9.10E-03		
Methylnaphthalene, 2-													
Naphthalene	4.45E+02	4.78E-01	2.13E+02	1.30E-04	2.37E-03		5.96E+02		5.96E+02			4.78E-01	
Nonane, n-	1.75E+03	2.72E+00	4.77E+03	5.44E-02	2.13E+01	2.87E-01	6.80E+05	1.95E+05	2.10E+06	6.02E+05	1.69E+02	2.72E+00	4.59E+02
OCDD	1.20E-02	1.90E+00	2.28E-02	2.27E+01	4.26E-02		3.16E+05		3.16E+05		2.75E-05	1.90E+00	5.24E-05
PCB-1260		6.19E-01		3.59E-01			1.25E+06		4.00E+06			6.19E-01	
Phenanthrene		2.89E-01		1.60E-03								2.89E-01	
Pyrene	1.17E+01	1.03E-01	1.20E+00	4.32E-03	5.21E-04	1.92E-03	3.40E+04	6.53E+01	5.00E+04	9.60E+01		1.03E-01	
Tetrachloroethene													
Toluene	3.86E+02	7.96E-01	3.07E+02	3.28E-05	8.43E-04		1.11E+04		1.11E+04		7.89E-01	7.96E-01	6.28E-01
Trichlorobenzene, 1,2,4-							6.02E+03		6.02E+03				
Trichloroethane, 1,1,1-							6.80E+01		6.80E+01				
Trichloroethene							1.28E+02		1.28E+02		1.42E-04		
Trichlorotrifluoroethane													
Trimethylbenzene, 1,2,4-		1.36E+00		3.20E-04		7.09E-06	1.73E+03	1.23E-02	1.73E+03	1.23E-02	7.16E-03	1.36E+00	9.72E-03
Xylenes	1.97E+03					2.86E-04	5.12E+02	1.46E-01	5.12E+02	1.46E-01	4.19E+00		

Ingestion Rates	Abbrev.	Value	Units	Remarks
Plant ingestion rate	IRf	8.13E-02	kg/kg/day	Meadow vole
Soil ingestion rate	IRsoil	1.95E-03	kg/kg/day	Meadow vole

4-23-96 ; 8:17AM ; EMCON ALASKA INC.→ 1303-831-3333;# 6/ 8
SENT BY:

EMCON Alaska, Inc.
4701 Business Park Boulevard • Suite 36 • Anchorage, Alaska 99503-7166 • (907) 562-3452 • Fax (907) 563-9814

FAX TRANSMITTAL

TO: John Hicks DATE: 3-26-96

FROM: Jim Daigle TIME: _____

Number of Pages 6 (Including Cover Page)

If you have received this communication in error, please notify us at the telephone number listed above.

Sender Note: Complete if applicable.

CLIENT: _____ Project/Task #: 5210.025.00

PHONE #: _____ FAX #: (303) 831-8208

Unless otherwise indicated or obvious from the nature of the transmittal, the information contained in this facsimile message is confidential information intended for the use of the individual or entity named above. If the reader of this message is not the intended recipient, or the employee or agent responsible to deliver it to the intended recipient, you are hereby notified that any dissemination, distribution or copying of this communication is strictly prohibited.

COMMENTS:

John

This is all the information I have

I did not talk To Dave Hertzog

The Environmental Firm which pulled the tanks at KSA is EMI in Anchorage – (907) 272-9336

Sorry I don't Know the P.M. for the project

Enviromental management

ORIGINAL TO FOLLOW: ____ ORIGINAL WILL NOT FOLLOW: ____ BROADCAST: ____

ANY QUESTIONS REGARDING THIS TRANSMISSION, PLEASE CALL THE NUMBER LISTED ABOVE

From the RI/FS KSA

3.10 Fire Training Area No. 1 (FT001)/Landfill No. 2 (LF006)

3.10.1 Site Description

Fire Training Area No. 1 is a circular depression, approximately 50 feet in diameter located approximately 2,000 feet north of Runway 29 and 1,500 feet east of Runway 36 (Map 1-1, Figure 1-3). This area has been in use monthly since 1980 for fire training exercises. The exercises involve the use of petroleum hydrocarbons, solvents, and fire retardant chemicals. These compounds could have been released to subsurface soil and groundwater. An AST was also present at the site but has been removed (SAIC, 1993a).

Petroleum compounds have been detected in groundwater around the central depression, and in a plume extending south towards Red Fox Creek.

The water table is between 13 and 18 feet bgs. The A-Aquifer is approximately 50 feet thick. Groundwater flow in the A-Aquifer is south towards Red Fox Creek (see cross-section Figure 1-7).

Landfill No. 2 is located approximately 150 feet northeast of Red Fox Creek and 2,000 feet north of Runway 29 (Map 1-1, Figure 1-3). The landfill was reportedly in operation between the 1950s until the 1960s. Based on the limited amount of information available concerning the types and quantities of the material disposed of at the landfill, it appears garbage, scrap metal, scrap equipment, and small volumes of shop wastes were placed in this landfill.

TCE was detected in soil gas in the northern part of the site, and in groundwater samples (SAIC, 1993a).

The water table is at approximately 15 feet bgs. Groundwater flow in the A-Aquifer is in a southerly direction. The top of the A-Aquitard was possibly tagged at 53 feet bgs in LF06-SB-01 (see cross-section Figure 1-7).

The highest concentration of contaminated soil (1,700 cy) was excavated from the site in July 1995. Soils were excavated from a 50-foot radius down to groundwater. Approximately 0.25 inch of free product was skimmed off of exposed groundwater.

3.10.2 Previous Investigation Results

Fire Training Area No. 1

SAIC, 1993a: A soil gas survey was performed in 1993 and consisted of advancing 38 soil gas monitoring points and analyzing the soil gas for HVOCs and VOCs. VOCs were

From the FT001 Report KSA

1 INTRODUCTION

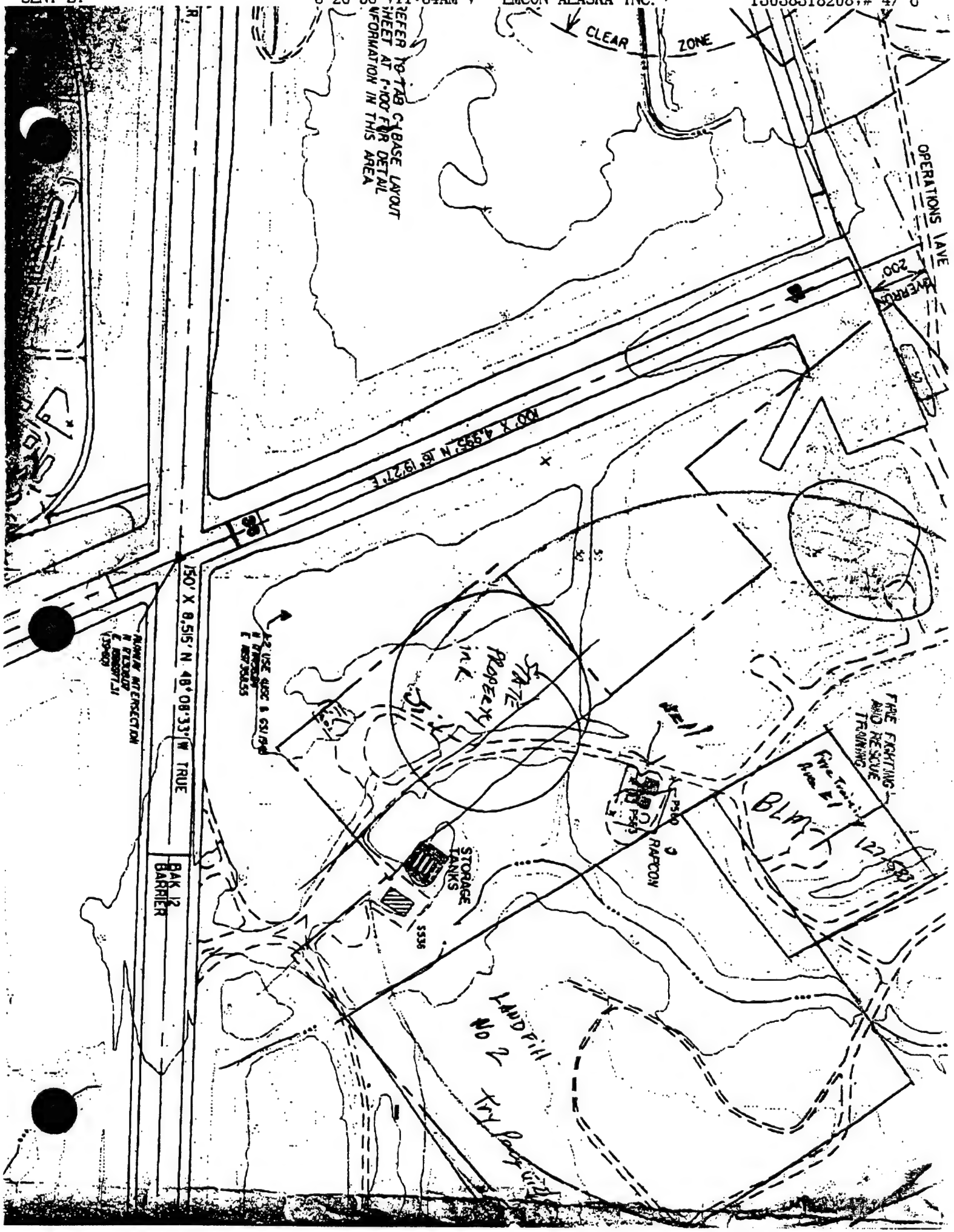
EMCON has been retained by the USACE, Alaska District, to investigate the source area and conduct excavation activities at FT001 located at the KSA, King Salmon, Alaska (Figure 1) under Contract Number DACA85-93-D0013, Delivery Order No. 0025. Planned activities to be conducted at FT001, involve the removal of approximately 1,500 cy of ~~gasoline~~-impacted soils, the collection of soil samples, and the stockpiling of impacted soil on site. The FT001 site is an Air Force Center for Environmental Excellence (AFCEE) natural attenuation study area. The U.S. Air Force (USAF) is performing this removal action to respond to an ADEC request for remedial action. This removal effort will be performed to remove the most heavily impacted soils from the center of the fire training area to reduce the human health and ecological risk posed by exposure to the site.

This removal action was conducted in accordance with the *Fire Training Area No. 1 Source Investigation and Excavation* workplan dated June 1995.

1.1 Site Description

King Salmon is located on the north bank of the Naknek River. The Naknek River is a westward flowing tidal river which discharges into Kvichak Bay, a portion of Bristol Bay located west of King Salmon. The King Salmon area is accessible only by air or water. The landscape has been glaciated. The KSA is set in a lowland area within the Naknek River basin. Ground surface elevations range from approximately 30 to 70 feet above mean lower low water level (mllw). The airstrip elevation is 58 feet above mllw.

FT001 is a circular depression, approximately 50 feet in diameter located approximately 2,000 feet north of Runway 29 and 1,500 feet east of Runway 36 (Figure 1). This area was used monthly from 1980 to approximately 1992 for fire training exercises. The exercises involve the use of petroleum hydrocarbons, solvents, and fire retardant chemicals. These compounds could have been released to subsurface soil and groundwater. An aboveground storage tank (AST) was also present at the site but has been removed (SAIC, 1993).


CLEAR ZONE
OPERATIONS AVE
200'
100' X 4,995' N 16° 19' 27" E
150' X 8,515' N 48° 08' 33" W TRUE
BAK 12 BARRIER
STATE PROPERTY
STORAGE TANKS
RAPCON
FIRE FIGHTING AND RESCUE TRAINING
LANDFILL No 2

UNDERGROUND FUEL STORAGE TANKS

KSL011

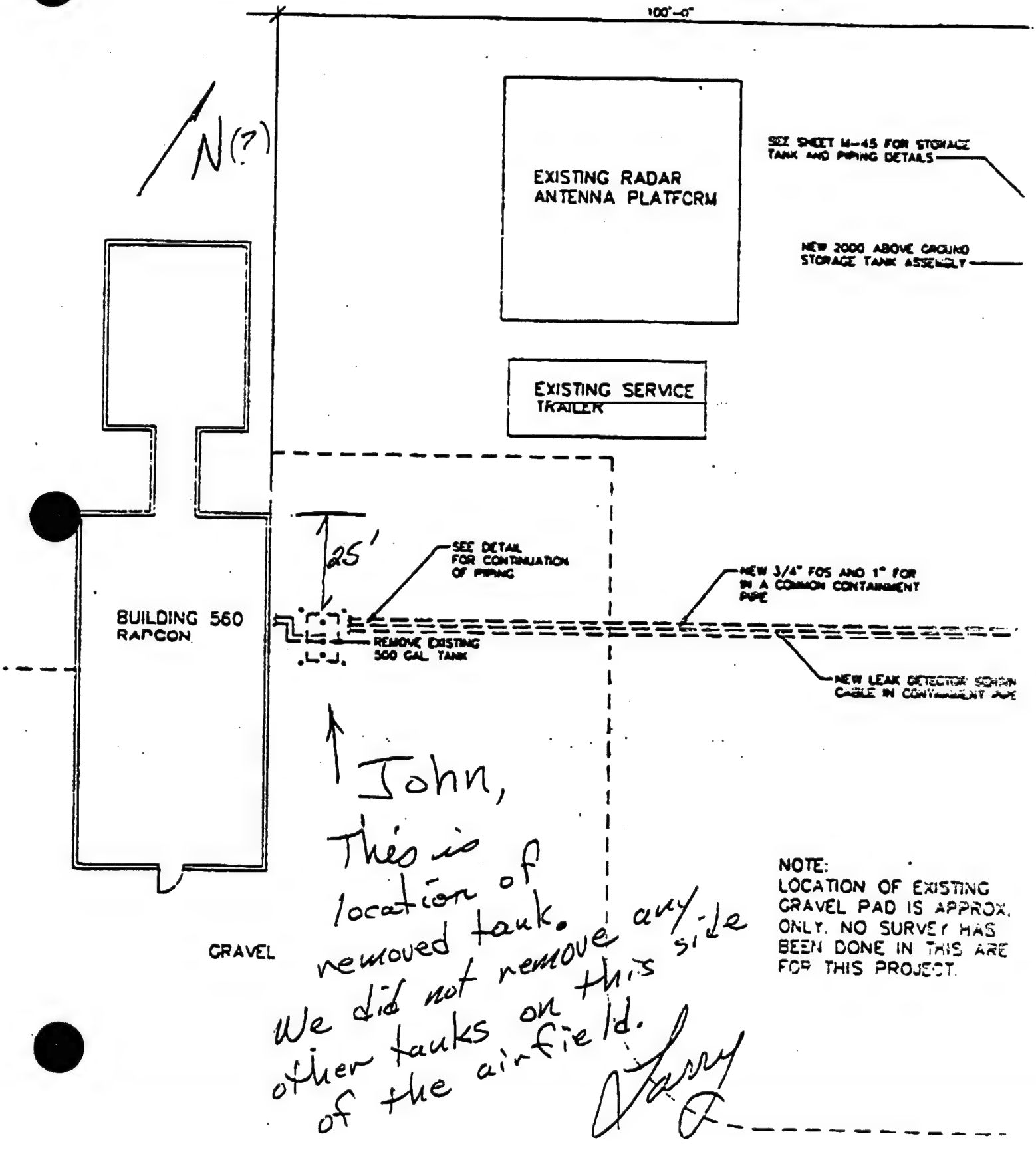
Drawing No.	Sheet No.	Title	Revision No.	Date
AF78-18-55	10	Bldg. 560 Tank Demolition Plan	None	93 Jul 30
"	11	Bldg. 638 Tank Demolition Plan	"	"
"	12	Bldg. 646 Tank Demolition Plan	"	"
"	13	Fence Details	"	"
"	14	Thaw Pipe Details	"	"
"	15	Typical Details	"	"
"	16	Bldg. 205 Mogas Station Sections and Details	"	"
		STRUCTURAL		
"	17	Tank Foundation Plans and Details	"	"
"	18	Building 205 Dispenser Islands	"	"
		MECHANICAL		
"	19	Mechanical Legend and Scope of Work	"	"
"	20	Equipment Schedule	"	"
"	21	Equipment Schedule	"	"
"	22	POL Tank Schedule	"	"
"	23	Building 154 Replace Tank 52	"	"
"	24	Building 154 1,500 Gal Tank Details	"	"
"	25	Building 154 Details	"	"
"	26	Building 162 Replace Tank 153	"	"
"	27	Building 162 1,500 Gal Tank Details	"	"

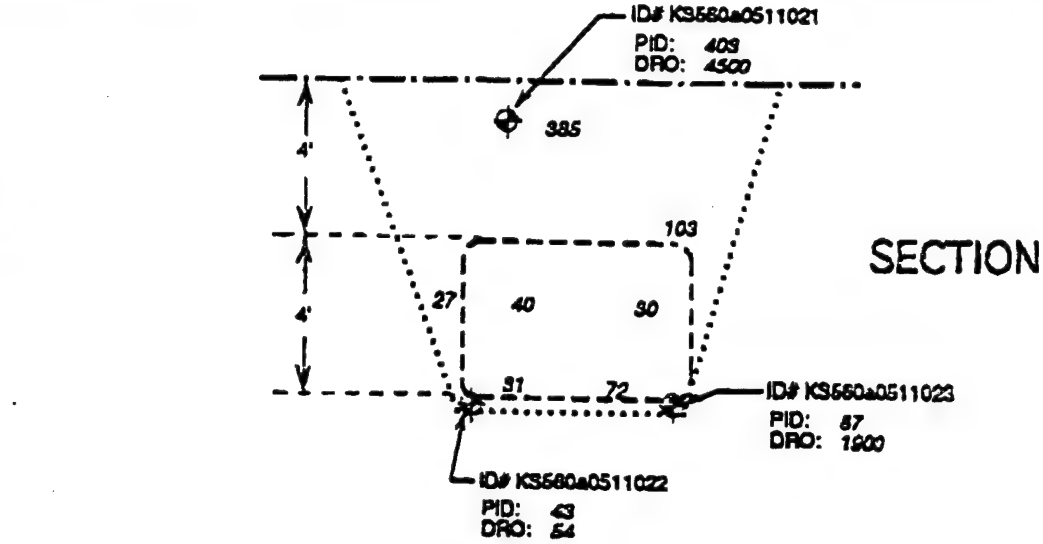
UNDERGROUND FUEL STORAGE TANKS

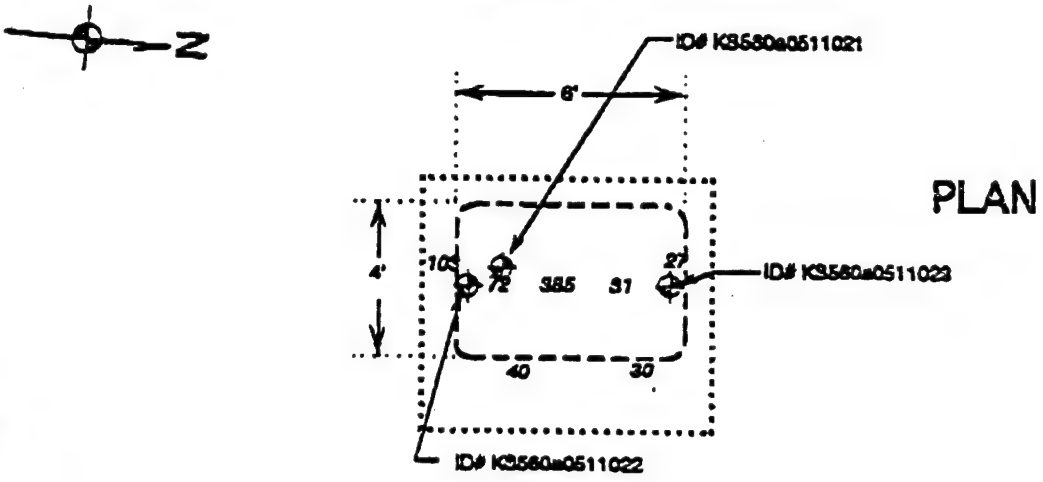
KSL011

Drawing No.	Sheet No.	Title	Revision No.	Date
AP78-18-55	44	Building 560 Replace Tank 560	None	93 Jul 30
"	45	Building 560 2,000 Gallon Tank Details	"	"
"	46	Building 560 Day Tank Installation	"	"
"	47	Building 638 Demolition Tank 638	"	"
"	48	Building 638 New Work, Tank 638	"	"
"	49	Building 638 New Work, Interior	"	"
"	50	Building 638 10,000 Gallon Tank Details	"	"
"	51	Building 638 10,000 Gallon Tank Details	"	"
"	52	Building 638 Diesel Transfer Pump Stand	"	"
"	53	Building 646 Replace Tank 646	"	"
"	54	Building 646 1,100 Gallon Tank Details	"	"
"	55	Signage	"	"
"	56	Identification of Tanks	"	"
"	57	Seismic Bracing Details	"	"
		ELECTRICAL		
"	58	Legend and Fixt. Schedule	"	"
"	59	Building 154 Plans and Details	"	"
"	60	Building 162 Plan	"	"

Post-it® Fax Note 7671	Date 3-28	# of pages ▶ 2
To John Hicks	From Larry	
Co./Dept.	Co.	
Phone #	Phone # 272-9336	
Fax (303) 831-8208	Fax #	



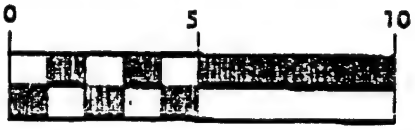




LEGEND

162	TOTAL ORGANIC VOLATILES AS MEASURED BY A PHOTOIONIZATION DETECTOR
DRO:	DIESEL RANGE ORGANICS
GRO:	GASOLINE RANGE ORGANICS
Pb:	LEAD
BTEX:	SUM OF BENZENE, TOULENE, ETHYL-BENZENE, AND XYLENES
.....	LIMITS OF EXCAVATION
- - - -	FORMER LOCATION OF UST
⊕	LABORATORY SAMPLE

ID# KS@@@@@@XX ← SAMPLE NUMBER
DATE MMDD
LOCATION
KING SALMON



Scale in Feet

ALL CONCENTRATION IN PARTS PER MILLION

DESIGN SHS
SHS
AH

REVISIONS
NO | DATE | BY

KING SALMON AIRPORT, ALASKA
BUILDING # 560
TANK # 560a
TANK PLAN AND SECTION VIEWS

KING SALMON UST REMOVAL PROJECT
U.S. ARMY ENGINEERING DISTRICT,ALASKA
CONTRACT No. DACA85-93-C-0054

DATE
EMI NO. 6018
R0
SHEET OF

APPENDIX C

LABORATORY ANALYTICAL DATA

MANTECH

Ref: 94-MW97/vg
94-LP97/vg

September 27, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
Post Office Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Attached are the results of 26 samples from King Salmon submitted to ManTech as part of S.R. #SF-0-76. The samples were received on September 23, 1994 and analyzed September 26, 1994. The methods used for analysis were EPA Method 353.1, 120.1, and Water's capillary electrophoresis method N-601. Quality assurance measures performed on this set of samples included spikes, duplicates, known AQC samples and blanks.

If you have any questions concerning these results please feel free to contact us.

Sincerely,

Mark White

Lynda Pennington
Lynda Pennington

xc: R.L. Cosby
J.L. Seeley jls

Sample	mg/l $NO^-_2 + NO^-_3(N)$	Cond.	mg/l Cl^-	mg/l SO^{-2}_4
KSWP-1	<.05	174	15.2	<.5
KSWP-2	<.05	245	20.7	2.01
KSWP-3	.13	85	16.4	1.66
KSWP-3. Dup	----	----	16.5	1.56
ESMW-2A	2.69	195	2.98	6.38
ESMW-2A Dup	2.73	----	----	----
ESMW-2B	.11	141	3.36	3.44
ESMW-3A	.05	97	2.80	2.85
ESMW-3B	.55	106	3.71	3.56
ESMW-4A	.6	120	3.57	4.00
ESMW-4A Dup	----	----	3.63	3.98
ESMW-4B	.40	81	3.88	2.61
ESMW-4B Dup	.40	81	----	----
ESMW-6B	.23	109	3.50	3.53
KSMW-ES7A	2.82	188	4.51	5.26
KSMW-7B	<.05	133	3.35	1.30
ESMW-12A	<.05	64	3.77	<.5
KSMW-51	<.05	368	3.28	1.09
KSMW-88	<.05	200	7.57	4.88
KSMW-91	.13	86	2.92	3.33
KSMW-92	.92	134	3.49	3.13
KSMW-92 Dup	----	----	3.43	3.14
KSMW-93	.34	80	2.71	2.97
KSMW-94	<.05	86	2.10	0.85
KSMW-94 Dup	<.05	----	----	----
KSMW-95	.06	141	3.07	1.96
KSMW-95 Dup	----	141	----	----
KSMW-435	<.05	276	2.79	2.78
KSMW-460B	.55	233	2.90	6.91
KSMW-460B Dup	----	----	3.12	6.86
KSMW-462C	.14	97	2.36	1.80
KSMW-501	.07	112	3.74	4.18
KSMW-508	<.05	45	3.43	2.06
KSMW-508 Rep	<.05	44	3.49	2.05
Blanks	<.05	1	<.5	<.5
AQC	2.75	----	107	73.7
True Value	2.81	----	106	75.0
Spike Recovery	102%	----	97%	98%

MANTECH

Ref: 94-MW96/vg
94-LP95/vg

September 26, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
Post Office Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Attached are the results of 11 samples from King Salmon submitted to ManTech as part of S.R. #RE-0-76. The samples were received on September 20, 1994 and analyzed immediately. The methods used for analysis were EPA Method 350.1, 120.1, and Water's capillary electrophoresis method N-601. Quality assurance measures performed on this set of samples included spikes, duplicates, known AQC samples and blanks.

If you have any questions concerning these results please feel free to contact us.

Sincerely,

Mark White

Lynda Pennington

Lynda Pennington

xc: R.L. Cosby
J.L. Seeley jls

Sample	mg/l $NO^-_2 + NO^-_3(N)$	Cond.	mg/l Cl^-	mg/l SO^{-2}_4
ESMW-1A	0.09	300	2.93	3.43
ESMW-1B	0.38	104	3.43	<.5
KSMW-50	No Sample Rec'd	48	1.94	<.5
KSMW-52	<.05	187	3.08	<.5
KSMW-53	0.09	108	6.12	<.5
KSMW-60	0.09	53	3.81	<.5
KSMW-60 Dup	----	----	3.84	<.5
KSMW-89	0.05	111	3.44	2.86
KSMW-90	0.07	90	3.72	2.61
KSMW-500	0.05	274	4.08	1.57
KSMW-506*	No Sample Rec'd	122	4.05	12.2
KSMW-506*	----	----	4.04	12.3
KSMW-509	0.07	No Sample Received		
Blanks	<.05	1	<.5	<.5
AQC	2.71	----	110	74.6
True Value	2.81	----	106	75.0
Spike Rec	100%	----	100%	101%

* Samples have identical labels

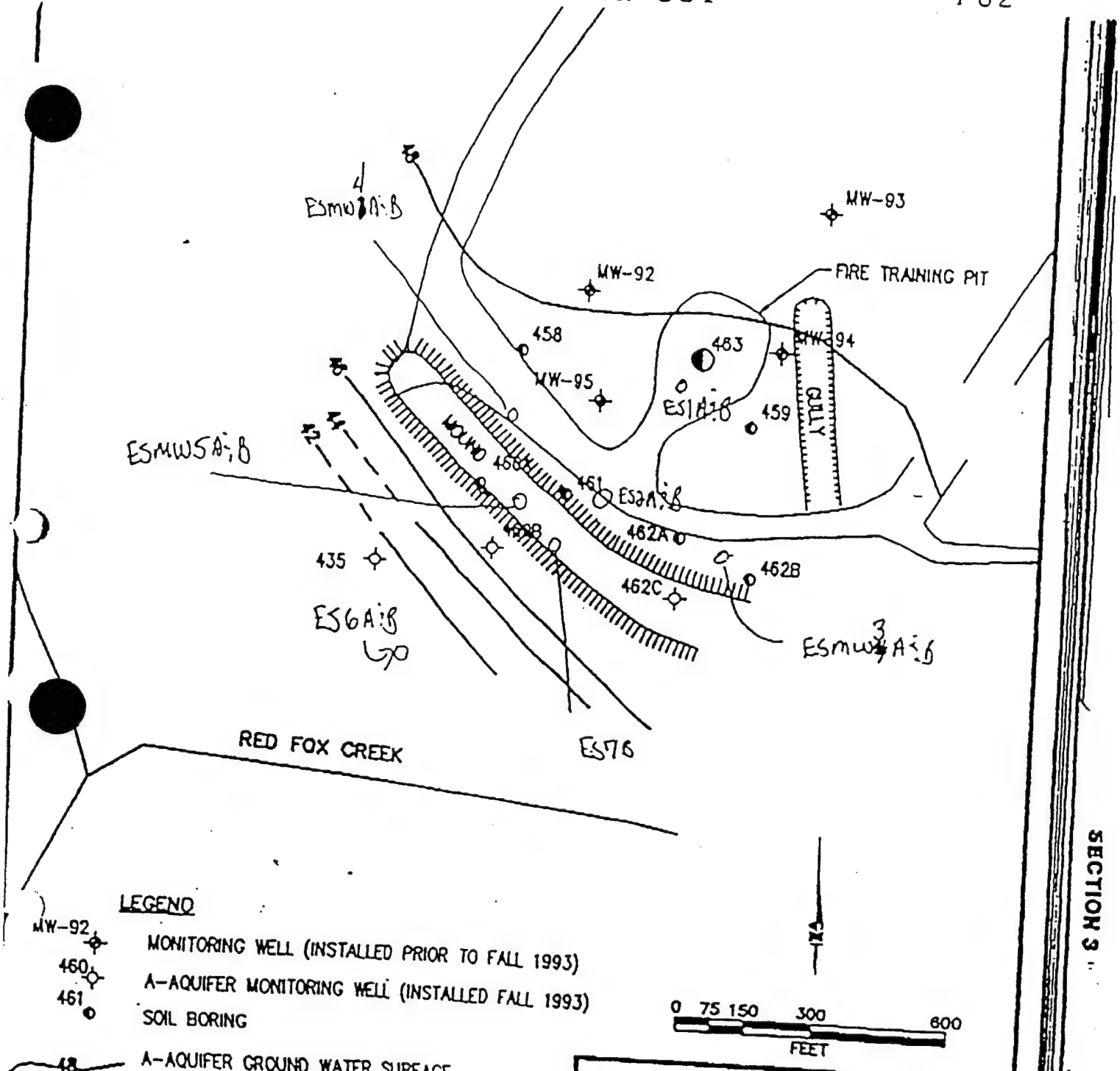


FIGURE 2.4

GROUND WATER ELEVATIONS AT SITE FT01 (OCTOBER 1993)

KING SALMON AIRPORT, AK EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

SOURCE: EMCON, 1994a

d: \45011\DRAWINGS\94DN0761, 08/26/94 at 10:52

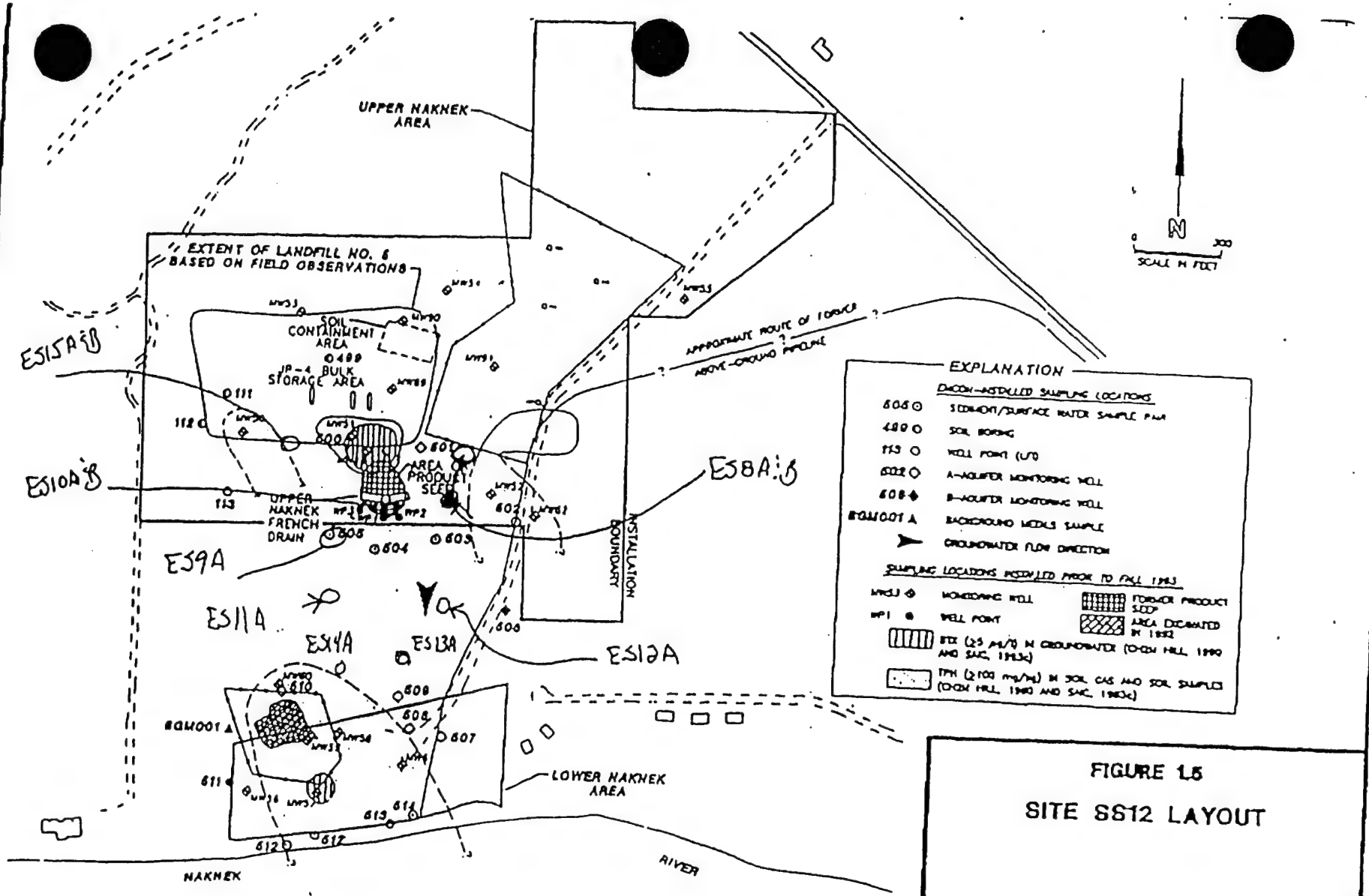


FIGURE 1.5

SITE SS12 LAYOUT

KING SALMON AIRPORT, AK EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

SOURCE: EMCON, 1994a

M:\45011\DRAWINGS\94DN0862, 08/09/94 at 10:54

10.25.94 10:49 AM *DENVER 551 P03

King Salmon AFB
Ground water Sampl

Sample	Date	Temp. C°	Depth TOC feet	Cond.	Total alkanity mg CaCO3/l	Ferrous Iron mg/l	Soluble Manganese mg/l	Dissolved oxygen mg/l	pH	Free carbon dioxide mg/l	Redox	Phenols mg/l
KSMW-435	9-14-94	5.0	18.34	264	116	<.05	0.5	2.0	7.1	10	214	
KSMW-94	9-14-94	9.0	11.54	82	36	<.05	<0.1	6.9	6.4	17	207	
KSMW-93	9-14-94	6.1	11.32	76	24	<.05	<0.1	6.6	6.1	40	220	
KSMW-92	9-14-94	5.0	16.54	118	45	<.05	<0.1	3.0	6.1	54	219	
KSMW-95	9-14-94	5.9	12.48	145	58	1.2	0.4	0.7	6.6	32	55	0.2
KSMW-460B	9-15-94	7.2	14.46	219	89	<.05	0.4	2.5	6.5	48	240	
KSMW-462C	9-15-94	6.8	5.40	94	41	<.05	<0.1	1.4	6.3	90	282	0.1
KSMWES-7A	9-15-94	5.9	12.08	180	43	<.05	0.2	9.0	6.3	36	266	
KSMWES-7B	9-15-94	5.0	11.60	128	55	<.05	0.1	0.7	6.5	40	262	
KSMW-51	9-15-94	7.0	9,88	402	205	11.4	0.7	0.1	6.6	100	-50	0.2
KSMW-501	9-16-94	5.2	12.9	109	18	<.05	<0.1	3.6	5.7	40	——	
KSMW-88	9-16-94	5.2	12.5	200	80	3.2	0.5	1.2	6.2	112	92	
KSMW-500	9-16-94	5.8	17.0	354	172	30.	0.3	0.2	6.4	165	-25	0.2
KSMW-90	9-16-94	5.8	16.28	84	33	<.05	<0.1	11.7	6.7	14	144	
KSMW-89	9-16-94	6.9	9.56	105	43	0.1	<0.1	0.3	6.2	34	143	
KSMW-52	9-17-94	8.3	3.52	210	93	5.9	0.3	0.5	6.4	60	-35	
KSMW-506	9-17-94	6.5	2.90	119	34	<.05	<0.1	0.3	7.7	8	-260	
KSMW-509	9-17-94	7.2	6.9	40	12	<.05	<0.1	4.8	5.7	32	183	
KSMW-60	9-17-94	7.1	7.5	52	15	<.05	0.1	4.3	5.8	40	200	
KSMW-50	9-17-94	7.8	9.5	47	14	<.05	<0.1	10.5	6.3	16	214	
KSMW-53	9-17-94	7.2	14.8	102	38	<.05	<0.1	10.9	6.3	14	195	
KSMW-1A	9-17-94	6.7	13.8	287	132	2.5	0.9	0.9	6.5	140	63	0.3
ESMW-8A	9-22-94	8.0	9.36	503	256	32.	0.8	0.3	6.5	280	-17	
ESMW-8B	9-22-94	6.7	9.26	175	80	<.05	<0.1	0.7	7.4	38	27	

King Salmon AFB

Ground water Sa[illegible]

Sample	Date	Temp. C°	Depth TOC feet	Cond.	Total Alkalinity mg/l (CaCO3)	Ferrous Iron mg/l	Soluble manganese mg/l	Dissolved oxygen mg/l	pH	Ferrous Chloride mg/l	Redox	Phenols mg/l
KSMW-1B	9-17-94	5.4	13.88	99	21	<.05	<0.1	2.1	6.9	10	202	
KSMW-3A	9-19-94	6.7	14.26	90	38	<.05	0.1	2.7	6.6	—	288	
KSMW-3B	9-19-94	5.9	14.82	108	44	<.05	<0.1	1.0	6.5	—	284	
KSMW-2A	9-19-94	8.2	15.62	185	67	<.05	—	4.4	6.5	—	288	
KSMW-2B	9-19-94	7.8	15.58	136	58	<.05	—	0.4	6.4	—	265	
KSWP-3	9-19-94	7.7	marsh surface	174	69	44.	<0.1	0.3	6.0	200	60	0.2
KSWP-2	9-19-94	9.8	11	286	140	15.	0.2	2.5	6.9	60	-50	
KSWP-1	9-19-94	8.7	11	190	96	8.0	0.1	1.0	6.4	80	37	
KSMW-4A	9-20-94	6.8	15.50	116	47	<.05	<0.1	7.0	6.2	401	280	
KSMW-4B	9-20-94	6.9	15.48	76	9	<.05	<0.1	2.5	7.0	12	271	
KSMW-6B	9-20-94	7.3	7.76	102	40	<.05	<0.1	4.0	6.4	24	297	
KSMW-12A	9-20-94	8.0	3.62	86	16	7.2	<0.1	0.8	6.1	106	180	
KSMW-9I	9-20-94	6.8	11.64	82	35	<.05	0.1	0.2	7.3	8	220	
KSMW-508	9-20-94	6.5	6.24	43	48	0.1	<0.1	4.4	6.1	36	215	
KSMW-5A	9-21-94	7.4	9.78	230	84	<.05	0.2	3.3	6.8	48	254	
KSMW-5B	9-21-94	5.6	7.12	132	57	<.05	<0.1	1.4	7.7	8	242	
KSMW-10A	9-22-94	6.9	2.08	200	98	<.05	0.1	0.8	6.3	4.6	253	
KSMW-10B	9-22-94	5.8	1.94	106	49	<.05	<0.1	6.7	7.2	12	255	
ESMW-15A	9-22-94	7.5	14.32	—	153	40.	0.5	1.8	6.2	>300	—	
ESMW-15B	9-22-94	7.5	14.42	—	136	0.2	0.3	0.2	7.0	42	—	
Well 507	9-22-94	7.8	4.26	—	68	0.2	<0.1	1.6	6.4	48	—	
ESMW-13A	9-23-94	4.0	4.5	—	119	20.	<0.1	0.1	6.5	176	—	
ESMW-14A	9-23-94	4.5	6.5	—	34	0.2	<0.1	0.7	6.5	94	—	

King Salmon Airport
Volatile fatty acids analyses by GC/MS.

all water samples contained some components of phenol/aliphatic/aromatic fatty acids. Their presence indicates that intrinsic remediation has or is occurring as the result of abiotic or biotic processes.

Water sample ESMW-8A had an organic functional group relative ratio as follows;

Fuctional Group	Percent of Total
aliphatics	72.3
phenols	4.6
aromatics	7.8
alkenyl/cycloalkylcarbonic	11.7
Dienoic/cycloalkenylcarbonic	3.6
Cyclodienylcarboxylic	0.0

Don Kamphell 11/1/94

ELEMENTAL CONSTI[redacted] ANALYSIS BY I[redacted]

THIS REPORT ([CLARK.ICAP]LIST.LST;3376) [redacted]ENERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	7196		7197		7198		7199		
STATION	KSMW-4A 9		KSMW-506		KSMW-3B		KSMW-6B		
TIME	08:54		08:56		08:58		09:00		
DATE	14-OCT-94		14-OCT-94		14-OCT-94		14-OCT-94		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.1100		1.1100		1.1100		1.1100		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	5.56	0.51	7.63	0.72	6.75	0.63	5.30	0.49	0.3446
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	1.00	0.58	5.74	0.58	1.13	0.58	1.28	0.58	0.5306
Ca	11.9	1.1	5.53	0.55	11.2	1.1	11.6	1.1	0.0109
Mg	4.11	0.40	4.28	0.42	2.68	0.26	2.48	0.24	0.0165
Fe	0.0361	0.0087	0.0341	0.0087	0.277	0.029	0.244	0.025	0.0078
Mn	0.239	0.026	0.120	0.014	0.127	0.015	0.024	0.010	0.0092
Co	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	0.0049
Mo	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0043
Al	0.071	0.070	<0.070	0.070	0.199	0.070	0.118	0.070	0.0636
As	<0.0052	0.0052	0.0082	0.0052	0.0086	0.0052	<0.0052	0.0052	0.0047
Se	<0.010	0.010	<0.010	0.010	<0.010	0.010	<0.010	0.010	0.0098
Cd	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031
Be	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	0.0004
Cu	<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267
Sb	<0.034	0.034	<0.034	0.034	<0.034	0.034	<0.034	0.034	0.0307
Cr	<0.0004	0.0004	0.0007	0.0004	0.0004	0.0004	0.0014	0.0004	0.0004
Ni	0.0065	0.0026	<0.0026	0.0026	0.0066	0.0026	0.0031	0.0026	0.0023
Zn	<0.010	0.010	<0.010	0.010	0.016	0.010	<0.010	0.010	0.0098
Ag	<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137
Tl	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0058
Pb	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0128
Hg	<0.098	0.098	<0.098	0.098	<0.098	0.098	<0.098	0.098	0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368
Te	<0.019	0.019	<0.019	0.019	<0.019	0.019	0.022	0.019	0.0172
Sr	0.0763	0.0075	0.0265	0.0025	0.0617	0.0061	0.0565	0.0056	0.0007
Ge	0.103	0.056	0.060	0.056	<0.056	0.056	<0.056	0.056	0.0512
V	<0.018	0.018	<0.018	0.018	<0.018	0.018	0.023	0.018	0.0170
Ba	0.0120	0.0026	0.0082	0.0026	0.0151	0.0026	0.0046	0.0026	0.0023
B	0.065	0.022	<0.022	0.022	0.024	0.022	<0.022	0.022	0.0206
Ti	<0.0065	0.0065	<0.0065	0.0065	0.0147	0.0065	0.0153	0.0065	0.0059

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

...ELEMENTAL CONSTI... ANALYSIS BY I...
THIS REPORT ([CLARK.ICAP]LIST.LST;3376) ...GENERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	7200		7201		7202		7203		
STATION	KSMW-91		KSMW-4B		KSMW-2B		KSMW-2A		
TIME	09:16		09:17		09:20		09:22		
DATE	14-OCT-94		14-OCT-94		14-OCT-94		14-OCT-94		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.1100		1.1100		1.1100		1.1100		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	4.81	0.44	5.45	0.50	6.83	0.64	8.43	0.80	0.3446
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	0.62	0.58	0.96	0.58	1.13	0.58	0.60	0.58	0.5306
Ca	7.73	0.77	7.55	0.75	14.8	1.4	19.0	1.9	0.0109
Mg	2.30	0.22	1.56	0.15	4.14	0.40	7.42	0.73	0.0165
Fe	0.0724	0.0088	0.476	0.048	0.0865	0.0099	0.0102	0.0087	0.0078
Mn	0.941	0.096	0.034	0.010	0.012	0.010	0.731	0.075	0.0092
Co	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	0.0049
Mo	0.0102	0.0048	0.0081	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0043
Al	<0.070	0.070	0.157	0.070	<0.070	0.070	0.123	0.070	0.0636
As	<0.0053	0.0053	0.0127	0.0052	<0.0052	0.0052	<0.0053	0.0053	0.0047
Se	<0.010	0.010	<0.010	0.010	<0.010	0.010	<0.010	0.010	0.0098
Cd	<0.0034	0.0034	0.0042	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031
Be	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	0.0004
Cu	0.051	0.029	0.034	0.029	<0.029	0.029	<0.029	0.029	0.0267
Sb	<0.034	0.034	0.034	0.034	<0.034	0.034	<0.034	0.034	0.0307
Cr	0.0009	0.0004	0.0007	0.0004	<0.0004	0.0004	0.0005	0.0004	0.0004
Ni	<0.0026	0.0026	<0.0026	0.0026	<0.0026	0.0026	0.0091	0.0026	0.0023
Zn	<0.010	0.010	<0.010	0.010	<0.010	0.010	<0.010	0.010	0.0098
Ag	<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137
Tl	<0.0065	0.0065	<0.0066	0.0066	<0.0065	0.0065	<0.0065	0.0065	0.0058
Pb	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0128
Hg	<0.098	0.098	<0.098	0.098	<0.098	0.098	<0.098	0.098	0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368
Te	<0.019	0.019	0.042	0.019	<0.019	0.019	<0.019	0.019	0.0172
Sr	0.0266	0.0026	0.0347	0.0034	0.0566	0.0056	0.109	0.010	0.0007
Ge	0.060	0.056	<0.056	0.056	<0.056	0.056	0.061	0.056	0.0512
V	<0.018	0.018	0.026	0.018	<0.018	0.018	<0.018	0.018	0.0170
Ba	<0.0026	0.0026	0.0081	0.0026	0.0050	0.0026	0.0238	0.0026	0.0023
B	<0.022	0.022	<0.022	0.022	<0.022	0.022	<0.022	0.022	0.0206
Ti	0.0258	0.0065	0.0418	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0059

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

...LEMENTAL CONSTI... ANALYSIS BY I...
THIS REPORT ([CLARK.ICAP]LIST.LST;3376) ...ENERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

PROJ...: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	7204		7205		7206		7207		
STATION	KSMW-508		KSMW-90		KSMW-60		KSMW-52		
TIME	09:24		09:26		09:29		09:30		
DATE	14-OCT-94		14-OCT-94		14-OCT-94		14-OCT-94		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.1100		1.1100		1.1100		1.1100		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	3.33	0.38	5.27	0.48	3.40	0.38	7.77	0.73	0.3446
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	<0.58	0.58	0.91	0.58	<0.58	0.58	1.57	0.58	0.5306
Ca	3.05	0.30	8.00	0.80	4.08	0.41	19.4	1.9	0.0109
Mg	0.893	0.083	2.05	0.19	1.26	0.12	6.30	0.63	0.0165
Fe	0.0729	0.0087	0.0248	0.0087	0.0351	0.0087	6.59	0.66	0.0078
Mn	0.034	0.010	<0.010	0.010	0.731	0.075	4.15	0.41	0.0092
Co	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	0.0049
Mo	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0043
Al	<0.070	0.070	0.109	0.070	<0.070	0.070	0.073	0.070	0.0636
As	0.0085	0.0052	0.0083	0.0052	<0.0053	0.0053	0.0184	0.0064	0.0047
Se	<0.010	0.010	<0.010	0.010	<0.010	0.010	<0.011	0.011	0.0098
Cd	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031
Be	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	0.0004
Cu	<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267
Sb	<0.034	0.034	0.042	0.034	<0.034	0.034	<0.034	0.034	0.0307
Cr	0.0007	0.0004	0.0013	0.0004	<0.0004	0.0004	0.0010	0.0004	0.0004
Ni	<0.0026	0.0026	0.0054	0.0026	<0.0026	0.0026	0.0062	0.0026	0.0023
Zn	<0.010	0.010	<0.010	0.010	<0.010	0.010	<0.010	0.010	0.0098
Ag	<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137
Tl	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0058
Pb	<0.014	0.014	0.016	0.014	<0.014	0.014	0.015	0.014	0.0128
Hg	<0.098	0.098	<0.098	0.098	<0.098	0.098	<0.10	0.10	0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368
Te	<0.019	0.019	0.022	0.019	<0.019	0.019	0.019	0.019	0.0172
Sr	0.0248	0.0024	0.0346	0.0034	0.0300	0.0029	0.104	0.010	0.0007
Ge	<0.056	0.056	<0.056	0.056	0.087	0.056	0.058	0.056	0.0512
V	<0.018	0.018	0.028	0.018	<0.018	0.018	0.021	0.018	0.0170
Ba	0.0042	0.0026	0.0054	0.0026	<0.0026	0.0026	0.0163	0.0026	0.0023
B	<0.022	0.022	<0.022	0.022	<0.022	0.022	<0.022	0.022	0.0206
Ti	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0059

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CONSTIT[illegible] ANALYSIS BY I[illegible]

THIS REPORT ([CLARK.ICAP]LIST.LST;3376) [illegible]ENERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	7208		7209		7210		7211		
STATION	KSMW-500		KSMW-53		KSMW-50		KSMW-509		
TIME	09:32		09:35		09:37		09:39		
DATE	14-OCT-94		14-OCT-94		14-OCT-94		14-OCT-94		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.1100		1.1100		1.1100		1.1100		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	7.29	0.68	6.10	0.56	3.48	0.38	3.27	0.38	0.3446
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	0.60	0.58	<0.58	0.58	<0.58	0.58	<0.58	0.58	0.5306
Ca	18.8	1.8	11.3	1.1	4.17	0.42	2.83	0.28	0.0109
Mg	10.5	1.0	2.41	0.23	0.939	0.087	0.863	0.080	0.0165
Fe	46.9	4.6	0.0405	0.0087	0.0835	0.0095	0.0218	0.0087	0.0078
Mn	3.57	0.35	<0.010	0.010	<0.010	0.010	0.289	0.031	0.0092
Co	0.0060	0.0054	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	0.0049
Mo	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0043
Al	<0.070	0.070	<0.070	0.070	<0.070	0.070	<0.070	0.070	0.0636
As	<0.0061	0.0061	<0.0052	0.0052	0.0059	0.0052	<0.0052	0.0052	0.0047
Se	<0.021	0.021	<0.010	0.010	0.015	0.010	<0.010	0.010	0.0098
Cd	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031
Be	0.0010	0.0005	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	0.0004
Cu	<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267
Sb	<0.037	0.037	<0.034	0.034	<0.034	0.034	<0.034	0.034	0.0307
Cr	0.0015	0.0005	<0.0004	0.0004	<0.0004	0.0004	<0.0004	0.0004	0.0004
Ni	0.0028	0.0026	<0.0026	0.0026	<0.0026	0.0026	<0.0026	0.0026	0.0023
Zn	0.031	0.010	<0.010	0.010	<0.010	0.010	<0.010	0.010	0.0098
Ag	<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137
Tl	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0058
Pb	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0128
Hg	<0.29	0.29	<0.098	0.098	<0.098	0.098	<0.098	0.098	0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368
Te	<0.019	0.019	<0.019	0.019	<0.019	0.019	<0.019	0.019	0.0172
Sr	0.142	0.014	0.0629	0.0062	0.0275	0.0026	0.0233	0.0022	0.0007
Ge	<0.056	0.056	<0.056	0.056	<0.056	0.056	<0.056	0.056	0.0512
V	<0.018	0.018	<0.018	0.018	<0.018	0.018	<0.018	0.018	0.0170
Ba	0.0394	0.0038	0.0039	0.0026	<0.0026	0.0026	0.0039	0.0026	0.0023
B	<0.023	0.023	<0.022	0.022	0.025	0.022	<0.022	0.022	0.0206
Ti	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0059

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CONSTI... ANALYSIS BY I...

THIS REPORT ([CLARK.ICAP]LIST.LST;337... GENERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	7212		7213		7214		7215		
STATION	KSWP-1		KSMW-1A		KSWP-3		KSMW-94		
TIME	09:41		09:43		09:45		09:49		
DATE	14-OCT-94		14-OCT-94		14-OCT-94		14-OCT-94		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.1100		1.1100		1.1100		1.1100		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	4.47	0.40	10.8	1.0	4.61	0.42	4.56	0.41	0.3446
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	<0.58	0.58	0.89	0.58	<0.58	0.58	0.79	0.58	0.5306
Ca	21.6	2.1	31.4	3.1	4.20	0.42	7.81	0.78	0.0109
Mg	6.14	0.61	11.7	1.1	1.63	0.16	2.00	0.19	0.0165
Fe	9.74	0.97	2.45	0.24	54.5	5.4	0.0698	0.0087	0.0078
Mn	1.65	0.16	6.25	0.62	0.077	0.010	<0.010	0.010	0.0092
Co	<0.0054	0.0054	0.0057	0.0054	0.0080	0.0054	<0.0054	0.0054	0.0049
Mo	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0043
Al	<0.070	0.070	<0.070	0.070	1.92	0.18	<0.070	0.070	0.0636
As	<0.0054	0.0054	<0.0075	0.0075	0.0065	0.0053	0.0231	0.0052	0.0047
Se	<0.011	0.011	<0.010	0.010	<0.022	0.022	0.014	0.010	0.0098
Cd	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031
Be	<0.0005	0.0005	<0.0005	0.0005	0.0028	0.0005	<0.0005	0.0005	0.0004
Cu	<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267
Sb	<0.034	0.034	<0.034	0.034	<0.038	0.038	0.042	0.034	0.0307
Cr	<0.0004	0.0004	0.0056	0.0005	0.0047	0.0005	<0.0004	0.0004	0.0004
Ni	<0.0026	0.0026	0.0040	0.0026	<0.0026	0.0026	0.0067	0.0026	0.0023
Zn	<0.010	0.010	<0.010	0.010	0.027	0.010	<0.010	0.010	0.0098
Ag	<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137
Tl	<0.0065	0.0065	<0.0065	0.0065	<0.0066	0.0066	<0.0065	0.0065	0.0058
Pb	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.016	0.014	0.0128
Hg	<0.10	0.10	<0.10	0.10	<0.35	0.35	<0.098	0.098	0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368
Te	<0.019	0.019	<0.019	0.019	<0.019	0.019	0.046	0.019	0.0172
Sr	0.0761	0.0075	0.195	0.019	0.0259	0.0025	0.0499	0.0049	0.0007
Ge	<0.056	0.056	<0.056	0.056	0.104	0.056	<0.056	0.056	0.0512
V	<0.018	0.018	<0.018	0.018	0.021	0.018	0.027	0.018	0.0170
Ba	0.0100	0.0026	0.0513	0.0049	0.0155	0.0026	0.0037	0.0026	0.0023
B	<0.022	0.022	<0.022	0.022	<0.023	0.023	<0.022	0.022	0.0206
Ti	<0.0065	0.0065	<0.0065	0.0065	0.0445	0.0065	<0.0065	0.0065	0.0059

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

...LEMENTAL CONST... ANALYSIS BY I...
THIS REPORT ([CLARK.ICAP]LIST.LST;3376 GENERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	7216		7217		7218		7219		
STATION	KSMW-1B		KSMW-88		KSMW-51		KSMW-501		
TIME	09:51		09:53		09:54		09:56		
DATE	14-OCT-94		14-OCT-94		14-OCT-94		14-OCT-94		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.1100		1.1100		1.1100		1.1100		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	6.38	0.59	6.14	0.57	9.52	0.91	6.62	0.62	0.3446
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	1.76	0.58	1.80	0.58	2.01	0.58	<0.58	0.58	0.5306
Ca	9.67	0.97	17.2	1.7	37.9	3.7	9.32	0.93	0.0109
Mg	2.73	0.26	8.76	0.87	16.3	1.6	4.53	0.44	0.0165
Fe	0.126	0.013	3.39	0.34	17.0	1.7	0.0463	0.0087	0.0078
Mn	0.172	0.019	3.90	0.39	8.04	0.80	0.276	0.029	0.0092
Co	<0.0054	0.0054	<0.0054	0.0054	0.0074	0.0054	<0.0054	0.0054	0.0049
Mo	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0043
Al	<0.070	0.070	<0.070	0.070	<0.070	0.070	0.093	0.070	0.0636
As	0.0151	0.0052	0.0075	0.0062	0.0235	0.0095	0.0066	0.0052	0.0047
Se	<0.010	0.010	<0.010	0.010	<0.011	0.011	<0.010	0.010	0.0098
Cd	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031
Be	<0.0005	0.0005	<0.0005	0.0005	<0.0006	0.0006	<0.0005	0.0005	0.0004
Cu	<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267
Sb	<0.034	0.034	<0.034	0.034	<0.034	0.034	<0.034	0.034	0.0307
Cr	<0.0004	0.0004	<0.0004	0.0004	0.0008	0.0004	<0.0004	0.0004	0.0004
Ni	0.0055	0.0026	<0.0026	0.0026	0.0053	0.0026	<0.0026	0.0026	0.0023
Zn	<0.010	0.010	<0.010	0.010	0.015	0.010	<0.010	0.010	0.0098
Ag	<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137
Tl	<0.0065	0.0065	<0.0065	0.0065	<0.0066	0.0066	<0.0065	0.0065	0.0058
Pb	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0128
Hg	<0.098	0.098	<0.10	0.10	<0.12	0.12	<0.098	0.098	0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368
Te	<0.019	0.019	<0.019	0.019	0.026	0.019	<0.019	0.019	0.0172
Sr	0.0584	0.0057	0.102	0.010	0.182	0.018	0.0678	0.0067	0.0007
Ge	<0.056	0.056	<0.056	0.056	<0.056	0.056	<0.056	0.056	0.0512
V	<0.018	0.018	<0.018	0.018	<0.018	0.018	<0.018	0.018	0.0170
Ba	0.0062	0.0026	0.0058	0.0026	0.0128	0.0026	0.0171	0.0026	0.0023
B	<0.022	0.022	<0.022	0.022	<0.022	0.022	<0.022	0.022	0.0206
Ti	0.0172	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0081	0.0065	0.0059

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CONSTI[illegible] ANALYSIS BY I[illegible]
THIS REPORT ([CLARK.ICAP]LIST.LST;3376[illegible] GENERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	7220		7221		7222		7223		
STATION	KSMW-5A		KSMWES-7B		KSMWES-7A		KSMW-460B		
TIME	09:58		10:02		10:03		10:05		
DATE	14-OCT-94		14-OCT-94		14-OCT-94		14-OCT-94		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.1100		1.1100		1.1100		1.1100		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	7.34	0.69	7.34	0.69	11.4	1.1	10.9	1.0	0.3446
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	2.95	0.58	1.60	0.58	0.94	0.58	1.67	0.58	0.5306
Ca	23.5	2.3	14.5	1.4	17.4	1.7	22.0	2.2	0.0109
Mg	10.1	1.0	3.20	0.31	4.85	0.48	9.05	0.90	0.0165
Fe	0.0133	0.0087	0.0296	0.0087	0.264	0.028	0.078	0.010	0.0078
Mn	1.53	0.15	0.267	0.029	0.98	0.10	2.85	0.28	0.0092
Co	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	0.0049
Mo	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0043
Al	0.110	0.070	<0.070	0.070	0.686	0.070	<0.070	0.070	0.0636
As	0.0250	0.0054	0.0110	0.0052	0.0083	0.0053	0.0229	0.0058	0.0047
Se	0.029	0.010	<0.010	0.010	<0.010	0.010	<0.010	0.010	0.0098
Cd	<0.0034	0.0034	0.0036	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031
Be	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	0.0004
Cu	<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267
Sb	0.050	0.034	<0.034	0.034	<0.034	0.034	<0.034	0.034	0.0307
Cr	0.0005	0.0004	<0.0004	0.0004	<0.0004	0.0004	<0.0004	0.0004	0.0004
Ni	0.0098	0.0026	0.0030	0.0026	0.0042	0.0026	0.0032	0.0026	0.0023
Zn	<0.010	0.010	<0.010	0.010	<0.010	0.010	<0.010	0.010	0.0098
Ag	0.018	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137
Tl	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0058
Pb	0.021	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0128
Hg	<0.098	0.098	<0.098	0.098	<0.098	0.098	<0.098	0.098	0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368
Te	0.052	0.019	<0.019	0.019	<0.019	0.019	0.025	0.019	0.0172
Sr	0.121	0.012	0.0818	0.0081	0.117	0.011	0.113	0.011	0.0007
Ge	<0.056	0.056	<0.056	0.056	<0.056	0.056	<0.056	0.056	0.0512
V	0.039	0.018	<0.018	0.018	<0.018	0.018	<0.018	0.018	0.0170
Ba	0.0323	0.0030	0.0120	0.0026	0.0267	0.0026	0.0077	0.0026	0.0023
B	<0.022	0.022	<0.022	0.022	<0.022	0.022	0.023	0.022	0.0206
Ti	<0.0065	0.0065	0.0091	0.0065	0.0170	0.0065	<0.0065	0.0065	0.0059

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CONSTI... ANALYSIS BY I...
THIS REPORT ([CLARK.ICAP]LIST.LST;3376 ...ENERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	7224		7225		7226		7227		
STATION	KSMW-5B		KSWP-2		KSMW-92		KSMW-95		
TIME	10:07		10:08		10:10		10:12		
DATE	14-OCT-94		14-OCT-94		14-OCT-94		14-OCT-94		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.1100		1.1100		1.1100		1.1100		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	7.05	0.66	4.98	0.45	6.45	0.60	5.50	0.50	0.3446
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	2.00	0.58	<0.58	0.58	<0.58	0.58	<0.58	0.58	0.5306
Ca	12.5	1.2	31.9	3.1	13.1	1.3	13.4	1.3	0.0109
Mg	4.24	0.41	8.68	0.86	3.26	0.32	4.85	0.48	0.0165
Fe	0.0519	0.0087	16.2	1.6	<0.0087	0.0087	1.23	0.12	0.0078
Mn	0.217	0.024	2.55	0.25	0.016	0.010	2.02	0.20	0.0092
Co	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	0.0049
Mo	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0043
Al	<0.070	0.070	<0.070	0.070	<0.070	0.070	<0.070	0.070	0.0636
As	0.0200	0.0052	<0.0057	0.0057	<0.0052	0.0052	0.0182	0.0055	0.0047
Se	<0.010	0.010	<0.011	0.011	<0.010	0.010	<0.010	0.010	0.0098
Cd	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031
Be	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	0.0004
Cu	<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267
Sb	<0.034	0.034	<0.034	0.034	<0.034	0.034	<0.034	0.034	0.0307
Cr	<0.0004	0.0004	<0.0004	0.0004	<0.0004	0.0004	<0.0004	0.0004	0.0004
Ni	0.0110	0.0026	0.0073	0.0026	<0.0026	0.0026	0.0045	0.0026	0.0023
Zn	0.017	0.010	0.056	0.010	<0.010	0.010	0.020	0.010	0.0098
Ag	<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137
Tl	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0058
Pb	0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0128
Hg	<0.098	0.098	<0.12	0.12	<0.098	0.098	<0.098	0.098	0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368
Te	0.025	0.019	<0.019	0.019	<0.019	0.019	0.027	0.019	0.0172
Sr	0.0630	0.0062	0.105	0.010	0.0772	0.0076	0.0797	0.0079	0.0007
Ge	<0.056	0.056	0.073	0.056	<0.056	0.056	<0.056	0.056	0.0512
V	0.019	0.018	<0.018	0.018	<0.018	0.018	<0.018	0.018	0.0170
Ba	0.0281	0.0026	0.0145	0.0026	<0.0026	0.0026	0.0043	0.0026	0.0023
B	<0.022	0.022	<0.022	0.022	<0.022	0.022	<0.022	0.022	0.0206
Ti	0.0233	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0059

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CONSTI[illegible] ANALYSIS BY I[illegible]

THIS REPORT ([CLARK.ICAP]LIST.LST;3376[illegible] GENERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	7228		7229		7230		7231		
STATION	KSMW-94		KSMW-89		KSMW-3A		KSMW-462C		
TIME	10:13		10:15		10:17		10:18		
DATE	14-OCT-94		14-OCT-94		14-OCT-94		14-OCT-94		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.1100		1.1100		1.1100		1.1100		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	3.46	0.38	5.09	0.46	4.43	0.40	5.45	0.50	0.3446
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	<0.58	0.58	0.75	0.58	<0.58	0.58	<0.58	0.58	0.5306
Ca	9.62	0.96	8.92	0.89	8.93	0.89	10.2	1.0	0.0109
Mg	2.61	0.25	4.48	0.44	3.16	0.31	2.92	0.28	0.0165
Fe	0.0366	0.0087	0.0792	0.0097	0.0121	0.0087	0.0193	0.0087	0.0078
Mn	<0.010	0.010	1.36	0.13	1.36	0.13	<0.010	0.010	0.0092
Co	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	0.0049
Mo	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0043
Al	<0.070	0.070	<0.070	0.070	<0.070	0.070	<0.070	0.070	0.0636
As	<0.0052	0.0052	<0.0054	0.0054	<0.0054	0.0054	<0.0052	0.0052	0.0047
Se	<0.010	0.010	<0.010	0.010	<0.010	0.010	<0.010	0.010	0.0098
Cd	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031
Be	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	0.0004
Cu	<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267
Sb	<0.034	0.034	<0.034	0.034	<0.034	0.034	<0.034	0.034	0.0307
Cr	<0.0004	0.0004	<0.0004	0.0004	<0.0004	0.0004	<0.0004	0.0004	0.0004
Ni	<0.0026	0.0026	0.0036	0.0026	<0.0026	0.0026	0.0026	0.0026	0.0023
Zn	<0.010	0.010	0.024	0.010	<0.010	0.010	<0.010	0.010	0.0098
Ag	<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137
Tl	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0058
Pb	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0128
Hg	<0.098	0.098	<0.098	0.098	<0.098	0.098	<0.098	0.098	0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368
Te	<0.019	0.019	<0.019	0.019	<0.019	0.019	<0.019	0.019	0.0172
Sr	0.0497	0.0049	0.0492	0.0048	0.0510	0.0050	0.0572	0.0056	0.0007
Ge	<0.056	0.056	0.070	0.056	0.058	0.056	<0.056	0.056	0.0512
V	<0.018	0.018	<0.018	0.018	<0.018	0.018	<0.018	0.018	0.0170
Ba	<0.0026	0.0026	0.0045	0.0026	0.0082	0.0026	0.0036	0.0026	0.0023
B	<0.022	0.022	<0.022	0.022	<0.022	0.022	<0.022	0.022	0.0206
Ti	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0059

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

...LEMENTAL CONSTIT... NALYSIS BY I...

THIS REPORT ([CLARK.ICAP]LIST.LST;3376) ...NERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

rechecked Pb.

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	7232		7233		7234		7235		
STATION	KSMW-435		KSMW-10A		KSMW-8A		ESMW-88		
TIME	10:20		10:22		10:23		10:25		
DATE	14-OCT-94		14-OCT-94		14-OCT-94		14-OCT-94		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.1100		1.1100		1.1100		1.1100		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	11.7	1.1	11.5	1.1	17.5	1.7	13.3	1.2	0.3446
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	0.92	0.58	2.64	0.58	2.71	0.58	2.54	0.58	0.5306
Ca	27.0	2.7	20.6	2.0	42.7	4.2	17.3	1.7	0.0109
Mg	10.6	1.0	6.53	0.65	16.8	1.7	4.39	0.43	0.0165
Fe	0.251	0.028	1.57	0.15	32.1	3.2	0.359	0.038	0.0078
Mn	5.27	0.53	1.29	0.13	14.9	1.4	2.21	0.22	0.0092
Co	<0.0054	0.0054	0.0058	0.0054	0.0169	0.0054	<0.0054	0.0054	0.0049
Mo	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0132	0.0048	0.0043
Al	<0.070	0.070	0.352	0.070	0.099	0.070	0.133	0.070	0.0636
As	<0.0070	0.0070	0.0108	0.0054	0.024	0.017	<0.0056	0.0056	0.0047
Se	<0.010	0.010	<0.010	0.010	<0.014	0.014	<0.010	0.010	0.0098
Cd	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031
Be	<0.0005	0.0005	<0.0005	0.0005	<0.0006	0.0006	<0.0005	0.0005	0.0004
Cu	<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267
Sb	<0.034	0.034	<0.034	0.034	<0.035	0.035	<0.034	0.034	0.0307
Cr	<0.0004	0.0004	0.0007	0.0004	0.0014	0.0004	<0.0004	0.0004	0.0004
Ni	<0.0026	0.0026	0.0053	0.0026	0.0090	0.0026	0.0043	0.0026	0.0023
Zn	<0.010	0.010	<0.010	0.010	0.012	0.010	0.014	0.010	0.0098
Ag	<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137
Tl	<0.0065	0.0065	<0.0065	0.0065	<0.0068	0.0068	<0.0088	0.0088	0.0058
Pb	<0.014	0.014	<0.014	0.014	0.094	0.014	<0.014	0.014	0.0128
Hg	<0.099	0.099	<0.098	0.098	<0.18	0.18	<0.098	0.098	0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368
Te	<0.019	0.019	<0.019	0.019	0.046	0.019	0.028	0.019	0.0172
Sr	0.131	0.013	0.111	0.011	0.355	0.035	0.0574	0.0057	0.0007
Ge	<0.056	0.056	<0.056	0.056	<0.056	0.056	<0.056	0.056	0.0512
V	<0.018	0.018	<0.018	0.018	0.023	0.018	<0.018	0.018	0.0170
Ba	0.0064	0.0026	0.0212	0.0026	0.109	0.010	0.0143	0.0026	0.0023
B	<0.022	0.022	<0.022	0.022	<0.022	0.022	<0.022	0.022	0.0206
Ti	<0.0065	0.0065	0.0279	0.0065	<0.0065	0.0065	0.129	0.012	0.0059

0.072 by ICP GF

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

MANTECH

Ref: 94-JH15/vg

September 29, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Attached are TOC results for a set of 38 groundwater samples submitted to ManTech September 13, 1994 under Service Request #SF-0-76. TOC determinations were begun and completed September 28, 1994 using RSKSOP-102.

A known AQC sample was analyzed with your samples for quality control. Sample numbers KSMW 3 Rep. 2 and ESMW 12A Rep 2, were filtered through a 0.45 μm Millipore filter and analyzed in duplicate due to high readouts.

If you have any questions concerning this data, please feel free to contact me.

Sincerely,

Jeff Hickerson

Jeff Hickerson

xc: R.L. Cosby
J.L. Seeley jls

DWATERS FROM KING SALMON FOR TOC (SR# SF-0-76)

SAMPLE	MG/L OC	SAMPLE	MG/L OC
ESMW 1A REP 2	27.3	KSMW 460 REP 2dup	5.8
ESMW 1A REP 2dup	27.2	KSMW 462C REP 2	4.8
ESMW 1B REP 2	1.6	KSMW 501 REP 2	7.6
KSMW 50 REP 2	1.3	KSMW 508 REP 2	1.4
KSMW 52 REP 2	16.4		
KSMW 53 REP 2	1.1	WPO32-I	43.6
KSMW 53 REP 2dup	1.1		44.1
KSMW 60 REP 2	2.1		44.3
KSMW 88 REP 2	3.9		43.4
KSMW 89 REP 2	2.3		43.3
KSMW 90 REP 2	4.0		43.5
KSMW 500 REP 2	17.7		43.4
KSMW 500 REP 2dup	17.7		43.7
KSMW 506 REP 2	0.7		
KSMW 509 REP 2	1.5		
KSWP 1 REP 2	7.9		
KSWP 2 REP 2	12.7		
ESMW 2A REP 2	6.5		
ESMW 2A REP 2dup	6.5		
ESMW 2B REP 2	2.6		
KSMW 3 REP 2	65.6		
KSMW 3 REP 2dup	65.9		
ESMW 3A REP 2	6.9		
ESMW 3B REP 2	1.3		
ESMW 4A REP 2	8.2		
ESMW 4A REP 2dup	8.2		
ESMW 4B REP 1	2.1		
ESMW 4B REP 2	2.2		
ESMW 6B REP 2	3.4		
ESMW ES 7A REP 2	2.7		
ESMW ES 7B REP 2	1.9		
ESMW ES 7B REP 2dup	2.0		
ESMW 12A REP 2	35.5		
ESMW 12A REP 2dup	35.5		
KSMW 51 REP 2	12.6		
KSMW 91 REP 2	0.7		
KSMW 92 REP 2	6.5		
KSMW 93 REP 2	4.3		
KSMW 93 REP 2dup	4.3		
KSMW 94 REP 2	1.4		
KSMW 95 REP 2	4.5		
KSMW 435 REP 1	5.5		
KSMW 435 REP 2	5.0		
KSMW 460 REP 2	5.8		

TRUE VALUE: WPO32-I = 44.0 MG/L OC

MANTECH

Ref: 94-BN52/vg

September 29, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Please find attached results for methane and ethylene on King Salmon, AK samples as per Service Request #SF-0-76. Samples were received on 9/23/94 and analyzed on 9/26-27/94. Samples were prepared as described in the paper "Dissolved Oxygen and Methane in Water by a GC Headspace Equilibration Technique", by Kampbell et al., in International Journal of Environmental Analytical Chemistry, Volume 36, pp. 249-257. Analysis and calculations were performed as per RSKSOP-147.

If you have any questions, please feel free to see me.

Sincerely,

Bryan Newell

Bryan Newell

xc: R.L. Cosby
J.L. Seeley jls
J.T. Wilson

ANALYZED 9/26/94

SAMPLE	METHANE	ETHYLENE
LAB BLANK	BLQ	ND
KSWP1	0.768	ND
KSWP2	1.351	ND
KSWP3	5.612	ND
ESMW2A	0.002	ND
ESMW2A LAB DUP	0.002	ND
ESMW2B	0.063	ND
ESMW3A	0.041	ND
ESMW3B	BLQ	ND
ESMW4A	0.002	ND
ESMW4B	BLQ	ND
ESMW4B FIELD DUP	BLQ	ND
ESMW6B	BLQ	ND
KSMW ES7A	BLQ	ND
KSMW ES7B	0.186	ND
ESMW12A	3.004	ND
KSMW51	0.162	ND
KSMW91	BLQ	ND
KSMW91 LAB DUP	BLQ	ND

ANALYZED 9/27/94

SAMPLE	METHANE	ETHYLENE
LAB BLANK	BLQ	ND
KSMW92	0.001	ND
KSMW93	0.004	ND
KSMW94	0.087	ND
KSMW95	0.060	ND
KSMW435	0.135	ND
KSMW435 FIELD DUP	0.137	ND
KSMW460B	BLQ	ND
KSMW462C	0.072	ND
KSMW501	0.004	ND
KSMW508	0.011	ND
KSMW508 LAB DUP	0.010	ND

SAMPLE	METHANE	ETHYLENE
10 PPM CH4	9.87	ND
100 PPM CH4	98.73	ND
990 PPM CH4	1011.95	ND
1 % CH4	1.01	ND
4 % CH4	4.08	ND
10 % CH4	9.97	ND
10 PPM C2H4	ND	10.01
100 PPM C2H4	ND	100.00

MANTECH

Ref: 94-MW99/vg
94-TH92/vg
94-LP101/vg

September 30, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Attached are inorganic results for a set of 14 samples from King Salmon, Alaska submitted to MERSC September 29 as a part of Service Request #SF-0-76. The analyses were done September 30 using EPA Methods 353.1 and 120.1 and Water's capillary electrophoresis method N-601.

Blanks, spikes, duplicates and known AQC samples were analyzed along with your samples for quality control.

If you have any questions concerning this data, please feel free to contact any one of us.

Sincerely,

Mark White

Tim Hensley

Lynda Pennington

Lynda Pennington

xc: R.L. Cosby
J.L. Seeley JLS

Sample	mg/L Cl^-	mg/L $SO_4^=$	mg/L NO^-_2+ NO^-_3(N)	µS/cm Conductivity
ESMW-5A	2.96	3.21	0.37	239
ESMW-5A Dup	----	----	----	240
ESMW-5B	3.51	2.79	0.11	134
ESMW-8A	4.33	<.5	0.06	432
ESMW-8B	2.57	1.36	0.06	182
ESMW-10A	4.57	8.54	0.30	204
ESMW-10B	3.53	2.40	0.10	110
ESMW-10B Dup	3.61	2.45	0.10	----
ESMW-12A	3.66	<.5	*	63.1
ESMW-12A Dup	----	----	----	63.1
ESMW-13A	4.16	.66	0.09	155
ESMW-14A	3.67	3.81	0.11	79.7
ESMW-15A	5.21	5.38	0.14	251
ESMW-15B	2.20	1.55	0.11	212
ESMW-15B Dup	2.15	1.56	----	----
KSMW-507	4.37	3.56	0.09	64.0
KSMW-50	*	*	0.26	*
KS-DK1A	3.12	3.04	*	334
Blank	<.5	<.5	<.05	.66
WP032	107	74.5	2.60	1413
WP032 T.V.	106	75.0	2.81	1413
Spike Rec.	98%	98%	101%	----

* No sample received for this parameter.

MANTECH

Ref: 94-LB39
October 5, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
919 Kerr Research Drive
Ada, OK 74820

THRU: Steve Vandegrift SV

Dear Don:

Please find attached the analytical results for Service Request SF-0-76 for the analysis of aqueous samples from King Salmon, AK, for the determination of BTEXXX & TMBs and Total Fuel Carbon. A total of 49 samples were received in capped, 40 mL VOA vials on September 23 & 29, 1994. Samples were analyzed between September 27 & October 5, 1994. Some of the samples arrived in duplicate. All samples were stored at 4°C until analyzed and were acquired and processed using the MAXIMA data system. A 5 point (1-1000 ppb) external calibration curve was used to determine the concentration for all compounds.

The QC True Value for all the compounds is 50 ppb.

RSKSOP-133 "Simultaneous Analysis of Aromatics and Total Fuel Carbon by Dual Column-Dual Detector for Ground Water Samples" was used for these analyses.

Sincerely,

Lisa R. Black

Lisa R. Black

xc: R.L.Cosby
J.L. Seeley jls

Reference to method 503.1

Purge: trap
2 columns: 2 detects
FID - most of everything - Total FID area count
PID - : divide sum of just BTEX
: TMB.
then take concentration from PID
then 0.85

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

Printed 05-Oc[redacted] 0-76 DP-P&T/GC-PID:FID A[redacted] r Dr. Kampbell Units=ng/mL A[redacted] ick

SAMPLE NAME	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	Fuel Carbon
100 PPB	9.70E+01	9.68E+01	9.70E+01	9.74E+01	9.73E+01	9.72E+01	9.75E+01	9.82E+01	9.85E+01	N/A
QC, OBSERVED, PPB	5.01E+01	5.02E+01	5.07E+01	5.04E+01	4.97E+01	5.10E+01	5.00E+01	5.05E+01	4.98E+01	N/A
GC LAB BLANK, PPB	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
ES MW-2A	ND	8.95E+00	BLQ	BLQ	2.49E+00	1.40E+00	ND	BLQ	BLQ	1.21E+01
ES MW-3A	9.13E-01	1.30E+01	BLQ	9.82E-01	2.72E+00	1.54E+00	ND	BLQ	ND	1.75E+01
ES MW-3B	ND	BLQ	ND	BLQ	BLQ	ND	ND	BLQ	ND	BLQ
KS MW-ES7A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-ES7B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-51	3.43E+00	2.05E+02	1.08E+02	1.31E+02	2.74E+02	1.47E+02	7.38E+01	1.01E+02	6.24E+01	1.56E+03
KS MW-88	ND	ND	BLQ	2.62E+00	BLQ	ND	6.17E+00	3.62E+00	1.45E+01	2.43E+02
KS MW-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-93	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10 PPB	9.21E+00	9.45E+00	9.62E+00	9.55E+00	9.54E+00	9.61E+00	9.65E+00	9.57E+00	9.73E+00	N/A
KS MW-94	ND	ND	ND	BLQ	ND	ND	ND	ND	ND	BLQ
KS MW-95	1.80E+02	4.70E+02	3.27E+01	3.88E+01	1.06E+02	6.60E+01	9.38E+00	2.50E+01	1.46E+01	8.76E+02
KS MW-435	5.86E+01	7.05E+00	6.76E+01	9.33E+01	1.38E+02	1.25E+02	2.79E+01	7.25E+01	4.18E+01	7.95E+02
KS MW-460B	ND	BLQ	ND	ND	ND	ND	ND	ND	ND	BLQ
KS MW-462C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-501	ND	ND	ND	ND	BLQ	ND	ND	ND	ND	BLQ
KS MW-501 Duplicate	ND	ND	ND	BLQ	BLQ	ND	ND	ND	ND	BLQ
ES MW-1A	1.05E+03	6.47E+03	3.58E+02	3.98E+02	1.17E+03	6.90E+02	9.09E+01	2.84E+02	1.80E+02	1.01E+04
ES MW-1B	5.59E+00	5.91E+01	2.09E+01	2.89E+01	8.72E+01	3.66E+01	6.57E+01	1.44E+02	8.14E+01	1.85E+03
KS MW-500	4.36E+00	8.07E+00	6.46E+01	1.05E+02	1.27E+02	1.07E+02	1.09E+02	2.18E+02	1.60E+02	2.18E+03
GC LAB BLANK, PPB	ND	BLQ	ND	ND	ND	ND	ND	ND	ND	N/A
1000 PPB	9.77E+02	9.38E+02	9.28E+02	9.29E+02	9.29E+02	9.39E+02	9.59E+02	9.65E+02	9.79E+02	N/A
KS MW-50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-52	2.31E+01	9.43E+00	2.83E+01	2.00E+01	3.74E+00	1.70E+00	3.41E+00	ND	3.62E+00	2.50E+02
KS MW-52 Duplicate	2.46E+01	1.02E+01	3.08E+01	2.20E+01	3.72E+00	1.85E+00	3.26E+00	ND	4.63E+00	3.34E+02
KS MW-53	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-53 Duplicate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-89	ND	ND	BLQ	ND	ND	ND	ND	ND	ND	BLQ
KS MW-90	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-506	ND	6.60E+00	ND	ND	ND	ND	ND	ND	ND	7.77E+01
KS MW-509	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS IN-RIVER	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS IN-RIVER Duplicate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QC, OBSERVED, PPB	4.81E+01	4.81E+01	4.52E+01	4.82E+01	4.77E+01	4.92E+01	4.91E+01	4.98E+01	4.92E+01	N/A
ES MW-5A	4.55E+01	8.14E+00	3.85E+01	1.65E+02	1.39E+02	3.18E+02	5.65E+01	1.15E+02	9.19E+01	1.27E+03
ES MW-5B	ND	ND	9.22E-01	ND	BLQ	ND	ND	ND	ND	2.74E+01
ES MW-8A	2.74E+02	2.97E+03	3.75E+02	2.91E+02	6.90E+02	6.61E+02	1.24E+02	3.52E+02	3.34E+02	7.71E+03
ES MW-8B	ND	1.41E+00	BLQ	ND	BLQ	1.27E+00	BLQ	ND	3.05E+00	3.61E+01
KS WP-1	BLQ	BLQ	ND	BLQ	BLQ	BLQ	1.18E+00	1.20E+00	1.32E+00	6.66E+00
KS WP-2	1.04E+00	1.82E+00	ND	9.62E-01	ND	ND	ND	ND	ND	5.87E+00
KS WP-2 Duplicate	BLQ	1.56E+00	ND	BLQ	ND	ND	ND	ND	ND	3.14E+00
KS WP-3	1.69E+00	2.59E+01	ND	ND	ND	ND	ND	ND	ND	2.47E+01

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb; N/A = Not Analyzed

10 PPB	9.53E+00	9.82E+00	1.01E+01	9.96E+00	9.94E+00	9.97E+00	9.96E+00	9.91E+00	1.01E+01	N/A
ES MW-2B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ES MW-4A	ND	3.04E+00	ND	ND	1.28E+00	BLQ	ND	ND	ND	4.57E+00
ES MW-4B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ES MW-6B	ND	1.72E+00	ND	ND	BLQ	ND	ND	ND	ND	2.18E+00
✓ ES MW-9A	5.90E+00	ND	1.07E+01	7.80E+00	7.57E+00	5.08E+00	1.16E+00	1.03E+00	ND	4.92E+00
KS MW-91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-507	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-508	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
✓ ES MW-10A	1.40E+01	9.65E-01	2.07E+01	3.26E+01	3.47E+01	3.33E+01	1.61E+01	3.91E+01	3.65E+01	4.96E+02
✓ ES MW-10B	ND	ND	ND	BLQ	BLQ	BLQ	1.06E+00	1.53E+00	1.83E+00	1.52E+01
100 PPB	9.92E+01	9.90E+01	9.91E+01	9.85E+01	9.97E+01	9.89E+01	9.87E+01	9.83E+01	1.01E+02	N/A
ES MW-12A	4.96E+00	BLQ	ND	BLQ	ND	ND	ND	ND	ND	7.70E+00
ES MW-13A	3.12E+00	ND	1.34E+00	1.59E+00	BLQ	ND	ND	ND	ND	1.22E+01
ES MW-14A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ES MW-15A	ND	ND	2.50E+00	2.96E+00	ND	ND	ND	ND	1.18E+00	9.27E+01
ES MW-15B	BLQ	5.57E+00	1.72E+01	3.29E+01	6.50E+00	2.13E+00	2.56E+01	1.25E+00	1.57E+01	4.99E+02
QC, OBSERVED, PPB	4.85E+01	4.88E+01	4.95E+01	4.90E+01	4.85E+01	4.98E+01	4.89E+01	5.22E+01	4.95E+01	N/A

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb; N/A = Not Analyzed

MANTECH

Ref: 94-BN53/vg

October 11, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Please find attached results for methane and ethylene on King Salmon, AK samples as per Service Request #SF-0-76. Samples were received on 9/30/94 and analyzed on 10/3/94. Samples were prepared and calculations were done as per RSKSOP-175 (draft). Analysis was performed as per RSKSOP-147.

If you have any questions, please feel free to see me.

Sincerely,

Bryan Newell

Bryan Newell

xc: R.L. Cosby
J.L. Seeley
J.T. Wilson

SF-0-76 DATA

ANALYZED 10/3/94

SAMPLE	METHANE	ETHYLENE
LAB BLANK	BLQ	ND
ESMW5A	BLQ	ND
ESMW5B	0.002	ND
ESMW8A	3.582	0.005
ESMW8B	0.133	ND
ESMW10A	1.501	ND
ESMW10B	0.010	ND
ESMW10B LAB DUP	0.010	ND
ESMW13A	4.234	ND
ESMW14A	0.033	ND
ESMW15A	7.636	ND
ESMW15B	0.005	ND
KSMW507	0.011	ND
" FIELD DUP	0.013	ND

SAMPLE	METHANE	ETHYLENE
10 PPM CH4	10.00	ND
100 PPM CH4	103.12	ND
990 PPM CH4	1002.43	ND
1 % CH4	1.01	ND
4 % CH4	4.01	ND
10 % CH4	9.99	ND
10 PPM C2H4	ND	10.21
100 PPM C2H4	ND	99.98

LOWER LIMITS OF QUANTITATION

METHANE	ETHYLENE
0.001	0.003

UNITS FOR THE SAMPLES ARE mg/L.
UNITS FOR THE STANDARDS CORRESPOND TO THE UNITS IN THE SAMPLE COLUMN.

ND DENOTES NONE DETECTED.
BLQ DENOTES BELOW LIMIT OF QUANTITATION.

LOWER LIMITS OF QUANTITATION

METHANE	ETHYLENE
0.001	0.003

UNITS FOR THE SAMPLES ARE mg/L.
UNITS FOR THE STANDARDS CORRESPOND TO THE UNITS IN THE SAMPLE COLUMN.

ND DENOTES NONE DETECTED.
BLQ DENOTES BELOW LIMIT OF QUANTITATION.

MANTECH ENVIRONMENTAL TECHNOLOGY

Ref: 94-JH16/vg

October 12, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Attached are TOC results for 12 additional groundwater samples submitted to ManTech Environmental September 13, 1994 under Service Request #SF-0-76. TOC determinations were begun September 30, 1994 and completed October 11, 1994 using RSKSOP-102.

A known AQC sample was analyzed with your samples for quality control and samples ESMW 8A REP 2 and ESMW 15A REP 2 were analyzed in duplicate due to high readouts.

If you have any questions concerning this data, please feel free to contact me.

Sincerely,

Jeff Hickerson

Jeff Hickerson

xc: R.L. Cosby
J.L. Seeley

MORE GROUNDWATERS FROM KING SALMON FOR TOC (SR# SF-0-76)

SAMPLE	MG/L OC
ESMW 5A	5.7
ESMW 5B REP 2	1.4
ESMW 8A REP 2	70.0
ESMW 8A REP 2dup	69.8
ESMW 8B REP 2	4.0
ESMW 10A REP 2	9.9
ESMW 10A REP 2dup	10.4
ESMW 10B REP 2	2.6
ESMW 13A REP 2	12.4
ESMW 14A REP 2	2.2
ESMW 15A REP 2	24.9
ESMW 15A REP 2dup	24.6
ESMW 15B REP 2	5.6
ESMW 15B REP 2dup	5.5
KSMW 507 REP 1	1.6
KSMW 507 REP 2	1.6
KSMW 507 REP 2dup	1.6
WPO32-I	43.1
	45.0
	45.2
WPO32-II	8.5

TRUE VALUES: WPO32-I = 44.0 MG/L OC
WPO32-II = 9.60 MG/L OC

MANTECH

Ref: 94-JH17/vg

October 12, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Attached are TOC results for a set of 17 soil samples submitted to ManTech Environmental September 13, 1994 under Service Request #SF-0-76. TOC determinations were begun October 3, 1994 and completed October 12, 1994 using RSKSOP-102 and RSKSOP-120.

A Leco standard soil and a known AQC sample were both analyzed with your samples for quality control.

If you have any questions concerning this data, please feel free to contact me.

Sincerely,

Jeff Hickerson

Jeff Hickerson

xc: R.L. Cosby
J.L. Seeley

SOIL SAMPLES FROM [illegible]ING SALMON FOR T[illegible]# SF-0-76)

SAMPLES	SOIL FILT %TOC	SOLIDS %TOC	TOTAL %TOC	MEAN %TOC
KCECSB 1 14.5-16' #1	0.002	0.016	0.018	0.020
KCECSB 1 14.5-16' #2	0.002	0.020	0.022	
ESMW 1B 10-12' #1	0.009	0.028	0.037	0.036
ESMW 1B 10-12' #2	0.004	0.031	0.035	
ESMW 1B 12-14' #1	0.002	0.016	0.018	0.016
ESMW 1B 12-14' #2	0.002	0.012	0.014	
ESMW 2B 13-15' #1	0.002	0.015	0.017	0.018
ESMW 2B 13-15' #2	0.002	0.016	0.018	
ESMW 2B 13-15' #1A	0.002	0.021	0.023	0.022
ESMW 2B 13-15' #2A	<0.001	0.021	0.021	
ESMW 2B 17-19' #1	<0.001	0.012	0.012	0.015
ESMW 2B 17-19' #2	0.002	0.016	0.018	
ESMW 2B 40-42' #1	<0.001	0.018	0.018	0.017
ESMW 2B 40-42' #2	<0.001	0.016	0.016	
ESMW 3B 13-15' #1	0.002	0.015	0.017	0.018
ESMW 3B 13-15' #2	0.002	0.016	0.018	
ESMW 5B 13-15' #1	<0.001	0.015	0.015	0.016
ESMW 5B 13-15' #2	0.002	0.015	0.017	
ESMW 5B 16-18' #1	<0.001	0.017	0.017	0.017
ESMW 5B 16-18' #2	<0.001	0.016	0.016	
ESMW 7B 11-13' #1	0.002	0.014	0.016	0.016
ESMW 7B 11-13' #2	0.002	0.014	0.016	
ESMW 8B 12-14' #1	0.033	0.102	0.132	0.132
ESMW 8B 12-14' #2	0.030	0.102	0.132	
ESMW 8B 16-18' #1	<0.001	0.026	0.026	0.024
ESMW 8B 16-18' #2	0.002	0.019	0.021	
ESMW 10 0-2' #1	0.102	1.217	1.319	1.310
ESMW 10 0-2' #2	0.102	1.199	1.301	
ESMW 10 3-5' #1	0.066	0.720	0.786	0.759
ESMW 10 3-5' #2	0.067	0.664	0.731	

SAMPLES	SOIL FILT %TOC	SOLIDS %TOC	TOTAL %TOC	MEAN %TOC
ESMW 10 13-15' #1	0.147	0.923	1.070	1.053
ESMW 10 13-15' #2	0.147	0.889	1.036	
ESMW 13B 4-5' #1	0.349	1.502	1.851	1.878
ESMW 13B 4-5' #2	0.356	1.548	1.904	
LECO		0.982		
		0.975		
		0.996		
WPO32-II	8.5 MG/L			
	8.7 MG/L			
	8.5 MG/L			
	8.4 MG/L			
	8.5 MG/L			

TRUE VALUES: LECO = 1.00 +/- 0.04%C
WPO32-II = 9.60 MG/L OC

MANTECH

Ref: 94-RC39/vg

November 1, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Attached is a report of the data generated from the analyses of 22 sample core extracts from King Salmon AFB, AK. The extracts, which were submitted under Service Request #SF-0-76, were analyzed for total fuel content as JP-4 jet fuel only. The reported values for fuel carbon were computed from the JP-4 determinations. I have also attached a report of the quality control analyses that were performed concurrently with the sample analyses.

Data quantification, peak identification, component concentration calculations, and dilution factor corrections were performed with MAXIMA chromatography software. JP-4 data was quantified with a 7-point external standard calibration curve ranging from 50-50,000 ng/µl.

The Minimum Quantifiable Limit of JP-4 in these samples is 15.03 µg/g. Please refer to ManTech report letter 93-RC19/vg, dated October 29, 1993, for a detailed explanation of the calculations used to arrive at this value.

Sample extracts were received October 3, 1994. Analyses were started October 12, 1994 and completed October 14, 1994. Sample extracts and quality control samples were analyzed according to RSKSOP-72, Rev. #1, excepting the modifications listed in the attached outline.

Sincerely,

Randy Callaway

Randy Callaway

xc: R.L. Cosby
J.L. Seeley jls

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

SR#SF-0 Kampbell / King Salmon AFB all conc. are

Sample	Dilution Factor	JP-4	Fuel Carbon (JP-4 x 0.85)
ES1B 10-12'	1	2130.00	1810.00
ES1B 10-12' TCE	1	1670.00	1420.00
ES1B 12-14'	1	8.03	6.83
ES1B 12-14' TCE	1	7.26	6.17
ES2B 13-15'	1	0.09	0.08
ES2B 17-19'	1	0.07	0.06
ES2B 40-42'	1	0.38	0.33
ES3B 13-15'	1	0.27	0.23
ES5B 13-15'	1	0.03	0.02
ES5B 16-18'	1	0.32	0.27
ES7B 11-13'	1	0.13	0.11
ES7B ?	1	0.83	0.71
ESMW8 16-18'	1	11.00	9.35
ESMW8B 12-14'	1	36.00	30.60
ESMW10 0-2'	1	36.60	31.10
ESMW10 3-5'	1	7.85	6.67
ESMW10 13-15'	1	3.12	2.65
ES10 0-2'	1	31.00	26.40
ES10 3-5'	1	28.60	24.30
ES10 13-15'	1	0.77	0.66
ES13B 4-5'	1	0.67	0.57
ECSB1 14.5-16'	1	0.18	0.15

NOTE: all reported values are corrected for dilution factors where applicable

LEMENTAL CONSTITUE[illegible] ALYSIS BY [illegible]
THIS REPORT ([CLARK.ICAP]LIST.LST;3376) W[illegible]NERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

PROJECT [illegible]LASKA WATER SAMPLES
WILSON/COOK
TA5

THIS REPORT WAS GENERATED WITH THE FOLLOWING INFORMATION:

ERROR LEVEL PERCENTAGE : 10%

STATISTICAL SENSITIVITES WITH A 2.0 SIGMA INTERVAL WERE USED

CONCENTRATION IN: MG/L

THE CONSTANT FILES USED:

[CLARK.ICAP]TYPE1.AMAX;1
[CLARK.ICAP]TYPE1.XQCA;1
[CLARK.ICAP]TYPE1.XQCB;1
[CLARK.ICAP]TYPE1.XQCC;1
[CLARK.ICAP]TYPE1.STD1;1
[CLARK.ICAP]TYPE1.STD2;1
[CLARK.ICAP]TYPE1.STD3;1
[CLARK.ICAP]TYPE1.STD4;1
[CLARK.ICAP]TYPE1.STD5;1
[CLARK.ICAP]TYPE1.XSS1;1
[CLARK.ICAP]TYPE1.XSS2;1
[CLARK.ICAP]TYPE1.FIXX;1
[CLARK.ICAP]TYPE1.LCN;54
LCN TIME: 11:10:15 LCN DATE: 14-OCT-94 FILTER FACTOR: 0.000002

THE DATA FILES USED:

[CLARK.ICAP]IC0001.DAT;2854
[CLARK.ICAP]TAG.DAT;2898
[CLARK.ICAP]OUTPUT.DAT;1941
[CLARK.ICAP]OUTPUT.LST;1858
[CLARK.ICAP]ARCH.DAT;15

SR#SF-0-7 Campbell / QC Table all conc. are ng/ul

Sample	Date Analyzed	JP-4
blank MeCl2	12OCT94	1.44
Method blank		2.82
100 ng/ul jp4		72.00
1000 ng/ul jp4		980.00
10000 ng/ul jp4		9470.00

MeCl2 = methylene chloride solvent blank
jp4 = JP-4 jet fuel standard

HP5890 GC - OPERATING CONDITIONS

A. Instrument Control
   1. Analyses: "EGLIN AFB"
   2. Program: "RWC-AS10"
   3. Calibration: "BTEX-13JUN94"

B. Temperature Program
   1. Initial Temp & Time: 10°C for 3.00 min
   2. Level 1: Rate = 4°C/min to 70°C, Final Time = 0.00
   3. Level 2: Rate = 1.0°C/min to 75°C, Final Time = 0.00
   4. Level 3: Rate = 10°C/min to 290°C, Final Time = 15.50
   5. Run Time: 60.00 min
   6. Oven Equilibration Time: 1.00 min

C. Miscellaneous
   1. Peak Width: 0.02
   2. Attenuation: 2^5
   3. Chart Speed: 0.50
   4. Threshold = 0
   5. Offset = 10%

II. MAXIMA PEAK INTEGRATION

A. Peak Detection Paramaters
   1. Baseline Points: 18
   2. Filter Window (in points): 9
   3. Intg. Sensitivity (coarse): 10.50 µV/sec
   4. Intg. Sensitivity (fine): 5.00 µV/sec
   5. Skim Ratio: 100.00

B. Peak Rejection Criteria
   1. Minimum Area: 2000 µV-sec
   2. Minimum Height: 300.0 µV
   3. Minimum Width: 3.00 sec

C. Integration Events
   1. 0.00: Disable Peak Skimming
   2. 0.00: Disable Peak Detection
   3. 7.00: Enable Peak Detection
   4. 21.97: Set Baseline
   5. 27.13: Set Baseline
   6. 32.30: Set Baseline
   7. 36.80: Set Baseline
   8. 39.59: Set Baseline
   9. 41.52: Set Baseline

III. MAXIMA DATA ACQUISITION

A. Preacquisition Delay: 7.00 min
B. Duration: 43.00 min
C. Rate: 3.00 points/sec
D. Run Time: 50.00 min

IV. MAXIMA CALIBRATION CURVES

A. JP-4
   1. Calibration Range = 50 - 50,000 ng/µl
   2. Summation of all peaks detected from 7.00 - 50.00 minutes

MANTECH

Ref: 94-JAD43

November 1, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

As requested in Service Request # SF-0-76, headspace GC/MS analysis of 25 King Salmon water samples for volatile organic compounds was completed. The samples were received on September 23, 29, 1994 and analyzed on October 17-19, 1994. RSKSOP-148 (Determination of Volatile Organic Compounds in Water by Automated Headspace Gas Chromatography/Mass Spectrometry (Saturn II Ion Trap Detector) was used for this analysis.

An internal standard calibration method was established for 10 chlorinated and 6 aromatic compounds. The standard curves were prepared from 1.0 to 4000 ppb. The lower calibration limits were 1.0 ppb.

The samples not requiring dilution were prepared by adding 10 ml of sample to a headspace vial containing 2 g of sodium chloride (NaCl). 8 µl of 125 µg/ml fluorobenzene was added to this 10 ml liquid volume before the vial was capped. The diluted samples were prepared by adding an appropriate volume of sample (X) to a headspace vial containing 2 g of NaCl and 10 - X ml of water. The internal standard was then added and the vial was capped.

A dilution corrected quantitation report for the samples, lab duplicates, field duplicates, QC standards, and lab blanks is presented in Tables 1 & 2.

If you should have any questions, please feel free to contact me.

Sincerely,

John Allen Daniel

xc: R.L. Cosby
G.B. Smith
D.D. Fine
J.L. Seeley jls

Table 1. Quantitation Report for S.R. # SF−0−76 from King Salmon.

Concentration = ppb

Compound	ESMW 1A	ESMW 1A Field Dup 1/2 Dil	ESMW 1B	ESMW 2A	ESMW 2B	ESMW 3A	ESMW 3B	ESMW 4A	ESMW 4A Field Dup	ESMW 4B
VINYL CHLORIDE	---	---	---	---	---	---	---	---	---	---
1,1−DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
T−1,2−DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
C−1,2−DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
1,1,1−TRICHLOROETHANE	7.5	7.0	---	1.3	---	---	---	---	---	---
CARBON TETRACHLORIDE	---	---	---	---	---	---	---	---	---	---
BENZENE	1160	1032	5.4	---	---	1.0	---	---	---	---
1,2−DICHLOROETHANE	---	---	---	---	---	---	---	---	---	---
TRICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
TOLUENE	*****	6770	52.7	8.9	---	12.8	---	3.0	3.1	---
TETRACHLOROETHENE	---	---	---	---	---	---	---	---	---	---
CHLOROBENZENE	---	---	---	---	---	---	---	---	---	---
ETHYLBENZENE	346	340	18.1	1.0	---	1.0	---	1.0	1.0	---
m+p−Xylene	1680	1570	102	3.5	---	3.8	---	2.0	1.8	---
o−Xylene	692	662	34.2	1.5	---	1.7	---	1.0	1.0	---

	ESMW 5A	ESMW 5A Lab Dup	ESMW 5B	ESMW 6B	KSMW−ES 7A	KSMW−ES 7B	ESMW 13A	ESMW 13A Lab Dup	KSMW 51	KSMW 88
VINYL CHLORIDE	---	---	---	---	---	---	---	---	---	---
1,1−DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
T−1,2−DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
C−1,2−DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
1,1,1−TRICHLOROETHANE	8.3	8.6	---	---	---	---	---	---	---	13.7
CARBON TETRACHLORIDE	---	---	---	---	---	---	---	---	---	---
BENZENE	46.8	47.8	---	---	---	---	2.6	2.6	3.1	---
1,2−DICHLOROETHANE	---	---	---	---	---	---	---	---	---	---
TRICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
TOLUENE	8.4	8.8	1.0	1.6	---	---	---	---	214	---
TETRACHLOROETHENE	---	---	---	---	---	---	---	---	---	---
CHLOROBENZENE	---	---	---	---	---	---	---	---	---	---
ETHYLBENZENE	36.8	36.0	1.1	---	---	---	1.4	1.4	109	1.0
m+p−Xylene	287	291	1.0	1.2	---	---	2.3	2.2	427	3.3
o−Xylene	302	318	---	1.0	---	---	1.0	1.0	156	---

Dil = Dilution Dup = Duplicate --- = Below Calibration Limit(1.0 ppb) ***** = Above Calibration Limit(4000 ppb)

Table 2. Quantitation Report for S[redacted]. # SF−0−76 from King Salmon.

Concentration = ppb

Compound	KSMW 92	KSMW 93	KSMW 93 Field Dup	KSMW 94	KSMW 95	KSMW 95 Lab Dup	KSMW 95 Field Dup	KSMW 435	KSMW 460B	KSMW 462C	KSMW 500
VINYL CHLORIDE	---	---	---	---	---	---	---	---	---	---	---
1,1−DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---	---
T−1,2−DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---	---
C−1,2−DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---	---
1,1,1−TRICHLOROETHANE	---	---	---	---	1.3	1.3	1.5	1.9	2.1	---	---
CARBON TETRACHLORIDE	---	---	---	---	---	---	---	---	---	---	---
BENZENE	---	---	---	---	199	197	198	35.6	---	---	2.9
1,2−DICHLOROETHANE	---	---	---	---	---	---	---	---	---	---	---
TRICHLOROETHENE	---	---	---	---	---	---	---	---	---	---	---
TOLUENE	---	---	---	---	494	473	506	3.2	1.0	---	3.2
TETRACHLOROETHENE	---	---	---	---	---	---	---	---	---	---	---
CHLOROBENZENE	---	---	---	---	---	---	---	---	---	---	---
ETHYLBENZENE	---	---	---	---	34.2	32.5	35.2	28.8	---	---	60.8
m+p−XYLENE	---	---	---	---	149	148	153	95.3	---	---	204
o−XYLENE	---	---	---	---	70.6	67.9	70.7	53.4	---	---	99.2

	KSMW 501	QC1017D 50 ppb	QC1017E 200 ppb	QC1017F 20 ppb	QC1017G 200 ppb	QC1017H 20 ppb	QC1017I 200 ppb	QC1019A 20 ppb	QC1019B 200 ppb	BL1017A BLANK	BL1017B BLANK
VINYL CHLORIDE	---	47.7	174	19.0	180	19.6	181	18.1	--- ***	---	---
1,1−DICHLOROETHENE	---	50.9	197	20.2	210	20.1	199	19.6	201	---	---
T−1,2−DICHLOROETHENE	---	48.7	206	20.8	209	20.8	205	21.0	207	---	---
C−1,2−DICHLOROETHENE	---	49.4	212	20.1	208	20.1	208	19.7	202	---	---
1,1,1−TRICHLOROETHANE	---	--- ***	201	20.6	203	20.7	206	20.0	203	---	---
CARBON TETRACHLORIDE	---	50.3	190	20.0	200	20.9	199	20.0	201	---	---
BENZENE	---	49.8	208	21.2	205	20.7	208	20.6	207	---	---
1,2−DICHLOROETHANE	---	52.4	214	22.2	203	20.4	217	21.9	209	---	---
TRICHLOROETHENE	---	50.6	217	22.9	215	22.6	221	25.8	228	---	---
TOLUENE	---	45.2	196	19.9	191	19.9	194	19.6	191	---	---
TETRACHLOROETHENE	---	49.0	195	19.1	202	20.3	196	19.4	204	---	---
CHLOROBENZENE	---	48.8	209	21.6	205	20.3	204	20.5	197	---	---
ETHYLBENZENE	---	46.7	190	18.1	189	19.8	188	19.0	190	---	---
m+p−XYLENE	---	46.8	389 **	37.2 *	380 **	36.6 *	374 **	37.1 *	377 **	---	---
o−XYLENE	---	45.2	203	20.3	201	19.8	193	19.8	202	---	---

Dup = Duplicate --- = Below Calibration Limit(1.0 ppb) * = 40 ppb ** = 400 ppb *** = Not Included in QC QC = Quality Control Std. BL = Blank

SP[redacted]-76 Dr. Kampbell

King Salmon, [redacted]/MSD Core Extracts

[redacted] mg/kg

SAMPLE	BENZENE	TOLUENE	EB	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB
ECSB1 14.5-16'	BLQ	7.17E-03	BLQ	BLQ	7.94E-03	6.15E-03	BLQ	6.53E-03	BLQ
ES-10 0-2'	2.10E-02	8.54E-03	1.53E-01	2.68E-01	3.64E-01	4.26E-01	5.06E-01	8.26E-01	5.69E-01
ES-10 3-5'	2.99E-02	1.22E-02	2.40E-01	3.71E-01	5.18E-01	4.51E-01	5.56E-01	9.63E-01	5.48E-01
ES-10 13-15'	BLQ	BLQ	BLQ	6.80E-03	BLQ	BLQ	ND	BLQ	ND
ES13B 4-5'	BLQ	BLQ	6.73E-03	8.08E-03	BLQ	5.89E-03	ND	BLQ	ND
ES1B 10-12'	1.61E+00	5.13E+01	1.31E+01	1.40E+01	4.03E+01	1.76E+01	1.09E+01	2.31E+01	8.91E+00
ES1B 12-14'	8.62E-01	2.76E+00	2.26E-01	2.54E-01	6.81E-01	3.85E-01	8.09E-02	2.40E-01	1.20E-01
ES2B 13-15'	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	ND	BLQ	BLQ
ES2B 17-19'	ND	BLQ	BLQ	BLQ	BLQ	BLQ	ND	ND	ND
ES2B 40-42'	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
ES3B 13-15'	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	ND	ND	ND
ES5B 13-15'	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	ND	BLQ	BLQ
ES5B 16-18'	ND	BLQ	ND	ND	ND	ND	ND	ND	ND
ES7B (7) 9-11'	1.48E-02	1.06E-01	1.76E-02	2.03E-02	5.54E-02	2.94E-02	1.15E-02	2.88E-02	1.24E-02
ES7B 11-13'	ND	BLQ	ND	ND	ND	ND	ND	ND	ND
ESMW10 0-2'	4.45E-02	1.38E-02	2.01E-01	3.45E-01	4.66E-01	5.26E-01	5.26E-01	9.29E-01	5.88E-01
ESMW10 3-5'	2.46E-02	1.53E-02	6.19E-02	9.82E-02	1.17E-01	1.15E-01	1.09E-01	2.01E-01	1.19E-01
ESMW10 13-15'	BLQ	BLQ	6.51E-03	1.06E-02	BLQ	BLQ	BLQ	6.40E-03	ND
ESMW8 16-18'	6.73E-03	5.73E-02	1.13E-02	1.26E-02	1.82E-02	2.03E-02	2.45E-02	4.51E-02	1.89E-02
ESMW8B 12-14'	7.36E-02	6.75E-01	1.05E-01	9.29E-02	1.71E-01	1.84E-01	9.49E-02	2.04E-01	1.36E-01
~~TGE~~ ES1B 10-12'	1.36E+00	3.97E+01	9.83E+00	1.04E+01	3.06E+01	1.34E+01	8.43E+00	1.83E+01	7.03E+00
~~TGE~~ ES1B 12-14'	5.17E-01	1.88E+00	1.72E-01	1.96E-01	5.24E-01	3.01E-01	7.22E-02	2.13E-01	1.08E-01

QC SUMMARY (ug/ml)

100	1.00E+02	1.00E+02	1.00E+02	9.98E+01	1.01E+02	1.00E+02	1.01E+02	1.01E+02	9.99E+01
10	1.07E+01	1.03E+01	1.04E+01	1.06E+01	9.98E+00	1.05E+01	1.08E+01	1.06E+01	1.03E+01
1 QC	9.77E-01	9.62E-01	9.79E-01	9.74E-01	9.46E-01	9.66E-01	9.69E-01	9.51E-01	9.49E-01
1	9.56E-01	9.63E-01	9.45E-01	9.47E-01	9.91E-01	9.62E-01	9.51E-01	9.73E-01	9.67E-01
1	9.25E-01	9.34E-01	9.06E-01	9.16E-01	9.65E-01	9.37E-01	9.34E-01	9.30E-01	9.49E-01
0.1	1.04E-01	1.04E-01	1.03E-01	1.01E-01	9.72E-02	1.01E-01	9.63E-02	1.06E-01	1.01E-01
0.1	9.31E-02	9.43E-02	9.42E-02	9.29E-02	9.44E-02	9.27E-02	8.80E-02	8.55E-02	9.43E-02
METHODBLANK	BLQ	ND	ND	ND	ND	ND	ND	ND	ND

Analyst: David A. Kovacs

BLQ<0.02 ug/ml

Printed: 10/21/94 1 of 1

MAR-31-1995 12:04 USEPA RSKERL-ADA SSB/SPB 405 436 8703 P.02

MANTECH

Ref: 95-JH52/vg

King Salmon

August 25, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Find attached results for methane on samples received on July 31, 1995 and analyzed on August 7, 8, 9, 10, and 14, 1995 under Service Request #SF-1-135 Mod. 1. Samples were prepared and calculations were done as per RSKSOP-175. Analyses were performed as per RSKSOP-147.

Sample # ESMW-10B was wasted due to loose septa caps on both duplicates. If you have any questions, feel free to contact me.

Sincerely,

Jeff Hickerson

Jeff Hickerson

xc: R.L. Cosby
J.L. Seeley JB
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

ANALYSIS PERFORMED 8-10-95

SAMPLE	METHANE
LAB BLANK	BLQ
GP-10	BLQ
EMCON-1	BLQ
EMCON-2	BLQ
WP-1	6.61
" FIELD DUP	6.89
GP-1	BLQ
GP-2	BLQ
GP-3	BLQ
GP-4	BLQ
MW51	0.115
" LAB DUP	0.108

ANALYSIS PERFORMED 8-14-95

SAMPLE	METHANE
LAB BLANK	BLQ
MW-52	0.432
MW-88	BLQ
" FIELD DUP	BLQ
MW-89	BLQ
MW-90	ND
" FIELD DUP	BLQ
MW-92	BLQ
MW-94	0.390
MW-500	0.400
MW-501	0.001
MW-506	0.052
" LAB DUP	0.048
10 PPM CH4	10.00
100 PPM CH4	99.93
1000 PPM CH4	1071.46
1% CH4	1.00
10% CH4	10.00

LIMIT OF QUANTITATION

METHANE
0.001

SAMPLE UNITS ARE mg/L.
STANDARDS UNITS CORRESPOND
TO THE SAMPLE COLUMN.

BLQ DENOTES BELOW LIMIT OF QUANTITATION
ND DENOTES NONE DETECTED.
NA DENOTES NOT ANALYZED.

MANTECH

Ref: 95-DK28/vg

September 6, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

King Salmon

Dear Dr. Kampbell:

This report contains the results of my GC/MSD analysis of King Salmon AFB core extracts for quantitation of benzene, toluene, ethylbenzene (EB), p-Xylene, m-Xylene, o-Xylene, 1,3,5-trimethylbenzene (1,3,5-TMB), 1,2,4-trimethylbenzene (1,2,4-TMB) and 1,2,3-trimethylbenzene (1,2,3-TMB) trichloroethene (TCE) and tetrachloroethene (PCE) as per Service Request #SF-1-135.

The analytical method was a modification of RSKSOP-124. Cool on-column injection (0.5 µl) was used with electronic pressure control set for a constant flow of 0.9 ml/min. A 30 m X 0.25 mm Restek Stabilwax (Crossbonded Carbowax-PEG, 0.5 µm film) capillary GC column with 9" X 0.53 mm ID uncoated capillary precolumn was used. The ions chosen were those listed in EPA method 524.2 Revision 3.0. Standards calibration ranged from 0.05 to 250 µg/ml. A complete report detailing the acquisition method and calibration curve have been recorded. The samples were extracted by Mark Blankenship August 2, 1995 and GC/MSD data acquisition was August 31, 1995.

If I can be of further assistance, please feel free to contact me.

Sincerely,

David A. Kovacs

xc: R.L. Cosby
J.L. Seeley
G.B. Smith

SR SF-1-135 King Salmon AFB Dr. Kampbell

GC/MSD ... core extracts

Units = mg/kg

FT01

Sample	Benzene	TCE	PCE	Toluene	EB	p-Xylene	m-Xylene	o-Xylene	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB
FT01-SS01	1.22E+00	ND	BLQ	4.43E+00	9.73E+00	1.19E+01	2.20E+01	1.03E+01	1.19E+00	3.29E+00	8.69E-01
FT01-SS01 DUP.	9.12E-01	ND	BLQ	3.79E+00	4.82E+00	5.40E+00	9.53E+00	5.41E+00	8.46E-01	1.62E+00	3.21E-01
FT01-SS02	ND	ND	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
FT01-SS02 DUP.	ND	ND	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
U.N. SS-3	ND	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	5.88E-02	4.31E-02
U.N. SS-3 DUP.	ND	ND	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
U.N. SS-4	BLQ	ND	BLQ	BLQ	8.48E-02	3.19E-01	1.21E-01	1.34E-01	2.34E-01	2.33E-01	1.73E-01
U.N. SS-4 DUP.	BLQ	ND	BLQ	BLQ	5.61E-02	2.06E-01	7.59E-02	6.37E-02	1.48E-01	1.53E-01	1.09E-01
U.N. SS-05	BLQ	ND	ND	BLQ	BLQ	5.38E-02	4.58E-02	6.30E-02	3.96E-02	5.18E-02	4.21E-02
U.N. SS-05 DUP.	BLQ	ND	BLQ	BLQ	1.01E-01	1.21E-01	1.37E-01	1.72E-01	1.60E-01	1.70E-01	1.73E-01
U.N. SS-06	ND	ND	ND	ND	BLQ	BLQ	BLQ	BLQ	BLQ	5.93E-02	BLQ
U.N. SS-06 DUP.	BLQ	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	3.73E-02	BLQ
Check Standards (ug/ml)											
Method Blank	ND	ND	ND	BLQ	ND	ND	BLQ	BLQ	ND	ND	ND
250	2.61E+02	2.61E+02	2.65E+02	2.55E+02	2.37E+02	2.70E+02	2.39E+02	2.52E+02	2.68E+02	2.50E+02	2.58E+02
250	2.39E+02	2.39E+02	2.35E+02	2.46E+02	2.27E+02	2.31E+02	2.61E+02	2.48E+02	2.63E+02	2.55E+02	2.42E+02
5	4.54E+00	4.92E+00	4.83E+00	4.88E+00	4.64E+00	4.46E+00	4.83E+00	4.87E+00	5.32E+00	5.67E+00	4.72E+00
5	4.88E+00	4.85E+00	4.27E+00	4.60E+00	5.29E+00	5.40E+00	5.38E+00	5.39E+00	5.32E+00	5.26E+00	5.22E+00

Analyst: A. Kovacs

BLQ < [illegible] ug/ml

Printed: 9/6/95

MANTECH ENVIRONMENTAL TECHNOLOGY

Ref: 95/JAD46

September 14, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

King Salmon

Dear Don:

As requested in Service Request # SF-1-135, headspace GC/MS analysis of 25 King Salmon water samples for tetrachloroethene (PCE), trichloroethene(TCE), dichloroethenes(DCE's) and vinyl chloride was completed. The samples were received on July 31 & August 2, 1995 and analyzed on August 16, 1995. RSKSOP-148 (Determination of Volatile Organic Compounds in Water by Automated Headspace Gas Chromatography/Mass Spectrometry (Saturn II Ion Trap Detector)) was used for this analysis.

An internal standard calibration method was established for the six compounds. The standard curves were prepared from 1.0 to 2000 ppb. The lower calibration limits were 1.0 ppb.

A quantitation report for the samples, lab duplicates, field duplicates, QC standards and lab blanks is presented in Table 1.

If you should have any questions, please feel free to contact me.

Sincerely,

John Allen Daniel

John Allen Daniel

xc: R.L. Cosby
G.B. Smith
D.D. Fine
J.L. Seeley JS

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

Table 1. Quantitation Report for S.R. # SF-1-135 from King Salmon.

Concentration = ppb

Compound	EMCON-1	EMCON 1 Field Dup	EMCON 1 Lab Dup	EMCON-2	ESMW-1A	ESMW-1B	ESMW-1B Lab Dup	EMSW-2A	ESMW-2B	ESMW-3A
VINYL CHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE	137	128	132	---	ND	ND	ND	ND	ND	ND
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Compound	ESMW4A	ESMW5A	ESMW5B	ESMW-8A	ESMW8B	ESMW-15A	ESMW15B	ESMW15B Lab Dup	MW-10A	MW-89
VINYL CHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Compound	MW-95 1/4 Dil	MW-95 Field Dup 1/2 Dil	MW-506	MW-460B	KSMW-653	GP-4	GP-6	GP-8	GP-9 1/2 Dil	GP-9 1/2 Dil Field Dup
VINYL CHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	1.0	---
TRICHLOROETHENE	ND	ND	ND	ND	24.2	---	14.1	ND	636	590
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	---	ND	ND

Compound	GP-10	QC0816A 20 ppb	QC0816B 200 ppb	QC0816C 20 ppb	QC0816D 200 ppb	QC0816E 20 ppb	QC0816F 200 ppb	QC0816G 20 ppb	QC0816H 200 ppb	BL0816A
VINYL CHLORIDE	ND	20.5	211	19.2	211	20.2	197	20.3	206	ND
1,1-DICHLOROETHENE	ND	20.0	198	20.1	200	21.2	191	20.1	184	ND
T-1,2-DICHLOROETHENE	ND	18.8	187	18.6	188	18.2	178	19.5	181	ND
C-1,2-DICHLOROETHENE	ND	17.6	188	18.5	194	17.9	186	18.0	189	ND
TRICHLOROETHENE	ND	21.5	194	21.3	203	22.4	197	21.6	199	ND
TETRACHLOROETHENE	ND	21.0	211	20.1	198	20.5	196	19.9	200	ND

ND = None Detected --- = Below Calibration Limit(1.0 ppb) Dup = Duplicate Dil = Dilution QC = Quality Control Std. BL = Blank

MANAGEMENT TECHNOLOGY

Ref: 95-LB57
August 9, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
919 Kerr Research Drive
Ada, OK 74820

THRU: Steve Vandegrift SV

Dear Don:

Please find attached the analytical results for Service Request SF-1-135, King Salmon Airport, requesting the analysis of up to 48 groundwater samples to be analyzed for BTEXXX, TriMBs, TetraMBs, Naphthalene and Total Fuel Carbon. A total of 57 samples were received, most in duplicate, in capped, 40 mL VOA vials on July 31-August 2, 1995. The samples were analyzed on August 2-7, 1995. The samples were stored at 4°C until analyzed. All samples were acquired and processed using the Millennium data system. A 1-500 ppb external calibration curve was used to determine the concentration of the TetraMBs, a 10-500 ppb external calibration curve was used to determine the concentration of Naphthalene, and a 1-1000 ppb external calibration curve was used to determine the concentration of the remaining compounds.

Please note: No duplicates were provided for the following samples "MW-653" and "GP-9". Both samples exceeded the calibration limit for Toluene therefore, a concentration **estimate** is provided for this compound and Total Fuel Carbon. Also, it was determined during analysis that Naphthalene has a 5% carry over rate.

RSKSOP-133 "Simultaneous Analysis of Aromatics and Total Fuel Carbon by Dual Column-Dual Detector for Ground Water Samples" was used for these analyses. Auto-sampling was performed using a Dynatech autosampler in-line with a Tekmar LSC 2000 sample concentrator.

Sincerely,

Lisa R. Black

Lisa R. Black

xc: R.L.Cosby
G.B. Smith
J.T. Wilson
J.L. Seeley JS

Print [redacted]/9/95 SF-1-135 DP-PT/GC-PID:FID [redacted]yses for Dr. Kampbell Units = ng/mL Analy[redacted] Black

Sample [redacted]e	BENZENE	TOLUENE	ETHYL[redacted]LENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TriMB
100 ppb	107	106	106	109	106	108	108
QC, OBSERVED, PPB	56.8	55.8	46.3	53.2	52.7	56.5	55.6
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	50.0
MW-10A	6.6	1.2	16.1	30.7	ND	24.3	11.6
MW-10B	ND	ND	ND	ND	ND	ND	ND
MW-50	ND	ND	ND	ND	ND	ND	ND
MW-51	4.7	88.6	49.6	54.7	61.1	40.0	36.5
MW-52	62.6	116	58.8	32.8	38.3	24.4	7.5
MW-88	ND	ND	BLQ	1.5	ND	ND	4.7
MW-89	BLQ	ND	1.8	2.5	2.9	2.4	8.2
MW-90	ND	1.4	BLQ	ND	BLQ	BLQ	ND
MW-92	ND	2.5	ND	ND	BLQ	ND	ND
MW-93	BLQ	5.6	BLQ	0.9	2.2	1.4	ND
10 PPB	10.2	9.9	10.0	10.2	9.9	10.1	10.2
MW-94	ND	BLQ	ND	ND	ND	ND	ND
MW-95	349	1010	90.3	99.0	290	180	33.2
MW-435	28.2	1.4	17.7	31.7	ND	2.2	10.6
MW-460B	BLQ	4.1	BLQ	BLQ	BLQ	BLQ	ND
MW-462C	ND	ND	ND	ND	ND	ND	ND
ESMW-500	BLQ	3.7	47.5	77.8	22.8	20.3	77.6
ESMW-500 Duplicate	BLQ	2.7	45.3	74.7	22.0	19.7	76.5
MW-501	ND	BLQ	BLQ	ND	ND	ND	ND
MW-506	ND	3.1	ND	ND	ND	ND	ND
MW-653	357	* 1420	200	210	559	385	95.7
100 PPB	113	108	107	105	109	106	108
WP-1	12.8	1.2	17.4	21.9	6.4	7.4	4.2
WP-2	3.2	BLQ	ND	BLQ	ND	BLQ	ND
WP-2 Duplicate	3.1	BLQ	ND	BLQ	ND	BLQ	ND
WP-3	1.6	21.3	ND	ND	ND	ND	ND
ESMW-1A	796	5400	399	371	1030	619	86.1
ESMW-1B	BLQ	1.2	ND	ND	BLQ	BLQ	ND
ESMW-2A	ND	0.9	ND	ND	BLQ	ND	ND
ESMW-2B	ND	ND	ND	ND	ND	ND	ND
ESMW-3A	ND	ND	ND	ND	ND	ND	ND
ESMW-4A	ND	ND	ND	ND	ND	ND	ND

* = Estimate of the concentration, no field duplicate provided to make dilutions

ND=None Detected; N/A=Not Analyzed; BLQ=Below Limit of Quantitation, 1ppb for all compounds except Naphthalene which = 10 ppb

Print[redacted]/9/95 SF-1-135 DP-PT/GC-PID:F[redacted]lyses for Dr. Kampbell Units = ng/mL An[redacted]L. Black

SampleName	1,2,4-TriMB	1,2,3-TriMB	1,2,4,5-TetraMB	1,2,3,5-TetraMB	1,2,3,4-TetraMB	Naphthalene	Fuel Carbon
100 ppb	109	109	111	109	114	112	N/A
QC, OBSERVED, PPB	56.9	53.8	54.2	57.3	60.1	58.9	N/A
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	N/A
MW-10A	29.8	24.9	10.4	13.7	21.7	29.6	518
MW-10B	ND	ND	ND	ND	ND	BLQ	BLQ
MW-50	ND	ND	ND	ND	1.1	BLQ	0.9
MW-51	33.7	27.3	17.0	21.4	33.3	60.5	1060
MW-52	1.6	9.5	6.8	12.2	22.8	BLQ	1050
MW-88	1.5	11.5	5.2	12.4	17.7	BLQ	433
MW-89	12.0	14.6	5.1	9.4	12.0	BLQ	388
MW-90	ND	ND	ND	ND	ND	ND	11.8
MW-92	ND	ND	ND	ND	ND	ND	3.2
MW-93	ND	ND	ND	ND	ND	ND	20.2
10 PPB	10.3	10.3	10.2	10.2	10.3	BLQ	N/A
MW-94	ND	ND	ND	ND	ND	ND	BLQ
MW-95	75.2	43.7	3.6	5.0	6.5	25.4	2240
MW-435	23.2	11.0	1.6	2.1	2.4	13.1	241
MW-460B	ND	ND	ND	ND	ND	ND	8.0
MW-462C	ND	ND	ND	ND	ND	ND	ND
ESMW-500	53.5	66.4	38.8	52.7	65.3	49.8	2420
ESMW-500 Duplicate	52.3	63.6	36.2	49.5	62.9	49.1	2070
MW-501	ND	ND	ND	ND	ND	ND	BLQ
MW-506	ND	ND	ND	ND	ND	ND	5.5
MW-653	272	146	17.7	27.2	41.5	127	* 4480
100 PPB	108	107	110	109	111	107	N/A
WP-1	7.9	6.5	4.1	5.2	9.8	18.8	416
WP-2	ND	ND	ND	ND	ND	ND	273
WP-2 Duplicate	ND	ND	ND	ND	ND	ND	336
WP-3	ND	ND	ND	ND	ND	ND	50.9
ESMW-1A	229	133	10.7	17.0	19.6	69.0	8980
ESMW-1B	ND	ND	ND	ND	ND	BLQ	4.8
ESMW-2A	ND	ND	ND	ND	ND	ND	1.2
ESMW-2B	ND	ND	ND	ND	ND	ND	ND
ESMW-3A	ND	ND	ND	ND	ND	ND	ND
ESMW-4A	ND	ND	ND	ND	ND	ND	ND

* = Estimate of the concentration, no field duplicate provided to make dilutions

ND=I , Detected; N/A=Not Analyzed; BLQ=Below Limit of Quantitation, b for all compounds except Naphthalene which = 10 ppb F 2 of 4

Prir 9/9/95 SF-1-135 DP-PT/GC-PID:FI alyses for Dr. Kampbell Units = ng/mL Ana .. Black

Sample Name	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TriMB
QC, OBSERVED, PPB	48.5	50.2	53.0	48.6	47.6	51.2	49.7
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	50.0
ESMW-5A	14.3	16.8	7.6	20.4	11.6	14.8	12.2
ESMW-5B	BLQ	ND	0.9	ND	ND	ND	ND
ESMW-6B	ND	ND	ND	ND	ND	ND	ND
ESMW-8A	319	5620	592	368	962	876	161
ESMW-8B	ND	BLQ	BLQ	ND	BLQ	BLQ	ND
ESMW-8B Duplicate	ND	BLQ	BLQ	BLQ	BLQ	BLQ	ND
ESMW-11	ND	1.3	ND	ND	ND	ND	ND
ESMW-12A	3.3	3.8	BLQ	BLQ	ND	ND	ND
ESMW-14	ND	ND	ND	ND	ND	ND	ND
ESMW-15A	BLQ	1.6	27.0	51.4	ND	1.1	79.5
1 PPB	0.9	0.9	0.9	0.9	0.9	0.9	0.9
ESMW-15B	ND	ND	4.8	11.0	ND	ND	6.9
ESMW-16	3.7	ND	1.7	1.6	ND	BLQ	ND
ESMW-16 Duplicate	3.5	ND	1.8	1.6	ND	BLQ	ND
GP-38? NO LABEL	ND	ND	ND	ND	ND	ND	ND
GP-1	ND	ND	ND	ND	ND	ND	ND
GP-2	BLQ	1.3	0.9	1.0	2.0	1.3	ND
GP-4	2.0	4.7	2.9	3.0	7.1	4.5	1.1
GP-5	2.2	1.6	1.0	1.0	2.3	1.5	BLQ
GP-6	2.1	1.5	1.0	1.1	2.4	1.5	BLQ
GP-6 Duplicate	9.8	9.8	9.9	10.0	10.0	10.0	9.9
10 PPB	ND	ND	ND	ND	ND	ND	ND
GP-7	ND	ND	ND	ND	ND	ND	ND
GP-8	1050	* 4150	706	679	1760	880	245
GP-9	ND	ND	ND	ND	ND	ND	ND
GP-10	319	755	456	448	1130	698	187
EMCON-1	BLQ	4.1	BLQ	BLQ	BLQ	BLQ	ND
EMCON-2	94.8	52.0	44.3	56.6	64.5	40.0	20.5
FT01 SW-1	4.8	3.5	ND	ND	BLQ	ND	ND
FT01 SW-02	ND	ND	ND	ND	ND	ND	ND
U.N. SITE SW-3	ND	BLQ	ND	ND	ND	ND	ND
U.N. SITE SW-4	ND	ND	ND	ND	ND	ND	ND
U.N. SITE SW-05	ND	ND	ND	ND	ND	ND	ND
U.N. SITE SW-06	46.7	50.5	52.0	47.1	47.5	50.0	50.0
QC, OBSERVED, PPB	50.0	50.0	50.0	50.0	50.0	50.0	50.0
QC, TRUE VALUE, PPB							

* = Estimate of the concentration, no field duplicate provided to make dilu[illegible]

ND = [illegible]e Detected; N/A=Not Analyzed; BLQ=Below Limit of Quantitation = [illegible]ppb for all compounds except Naphthalene which = 10 ppb

Dr. [illegible] Analyses for Dr. Kampbell

Units = ng/mL Analyst: L. Black

SampleName	1,2,4-TriMB	1,2,3-TriMB	1,2,4,5-TetraMB	1,2,3,5-TetraMB	1,2,3,4-TetraMB	Naphthalene	Carbon
QC, OBSERVED, PPB	50.4	47.3	45.5	48.3	49.2	42.8	N/A
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	N/A
ESMW-5A	22.1	11.4	2.7	3.3	4.4	21.3	275
ESMW-5B	ND	ND	ND	ND	ND	ND	1.3
ESMW-6B	ND	ND	ND	ND	ND	ND	N/A
ESMW-8A	470	398	25.6	65.6	129	225	13330
ESMW-8B	ND	BLQ	2.1	1.6	24.6	ND	94.7
ESMW-8B Duplicate	ND	BLQ	2.1	1.6	24.2	ND	99.7
ESMW-11	ND	ND	ND	ND	ND	ND	1.1
ESMW-12A	ND	ND	ND	ND	ND	BLQ	63.2
ESMW-14	ND	ND	ND	ND	ND	ND	ND
ESMW-15A	ND	27.9	27.1	39.2	52.0	73.8	1670
1 PPB	1.2	1.0	1.0	0.9	1.0	N/A	N/A
ESMW-15B	ND	12.9	15.7	17.9	37.8	30.6	552
ESMW-16	BLQ	ND	ND	ND	ND	ND	21.0
ESMW-16 Duplicate	1.3	1.1	1.8	1.9	3.1	BLQ	37.4
NO LABEL	ND	ND	ND	BLQ	1.6	BLQ	6.9
GP-1	ND	ND	ND	ND	ND	ND	ND
GP-2	ND	ND	ND	ND	ND	ND	BLQ
GP-4	1.0	ND	ND	ND	ND	ND	8.5
GP-5	3.4	1.2	ND	ND	ND	ND	37.3
GP-6	1.1	ND	ND	ND	ND	ND	24.7
GP-6 Duplicate	1.3	BLQ	ND	1.2	1.8	BLQ	34.0
10 PPB	10.1	10.1	10.3	10.3	11.2	12.8	N/A
GP-7	ND	ND	ND	ND	ND	ND	ND
GP-8	ND	ND	ND	ND	ND	ND	ND
GP-9	795	263	35.0	55.9	78.5	366	* 12800
GP-10	ND	ND	ND	ND	ND	ND	ND
EMCON-1 – FT01-FD9	556	209	26.8	42.7	60.2	230	6680
EMCON-2 FT01-FD8	ND	ND	ND	ND	ND	ND	5.8
FT01 SW-1	24.7	16.3	8.0	10.7	15.6	21.6	772
FT01 SW-02	ND	ND	ND	ND	ND	BLQ	7.6
U.N. SITE SW-3	ND	ND	ND	ND	ND	ND	ND
U.N. SITE SW-4	ND	ND	ND	ND	ND	ND	BLQ
U.N. SITE SW-05	ND	ND	ND	ND	ND	ND	ND
U.N. SITE SW-06	ND	ND	ND	ND	ND	ND	ND
QC, OBSERVED, PPB	49.5	45.9	44.2	47.1	47.2	41.9	N/A
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	N/A

* = Estimate of the concentration, no field duplicate provided to make dilutions

ND=None Detected; N/A=Not Analyzed; BLQ=Below Limit of Quantitation, 1ppb for all compounds except Naphthalene which = 10 ppb

MANTECH

Ref: 95-DF42

Aug 23, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

King Salmon

Dear Don:

This letter reports the first successful analysis of samples on the Bio-Rad Tracer GC/FTIR at RSKERL. Louis Staggs' and my efforts began last July with a trip to Conoco to run samples on their Tracer. Since then we experienced first hand the difficulties of bringing up a system which had been idle for over four years. We returned a MCT detector for re-evacuation of its Dewar, installed a new CO_2 trap system to minimize CO_2 background fluctuations in the purge gas, replaced an cracked ion gauge which was causing poor vacuum, modified an expansion loop in the GC and a connecting spacer between the xyz positioning platform and the transfer line block and installed a new transfer line. We now can align the tip and meet specifications for tip alignment without assistance from a service engineer.

Preliminary GC/MS Analysis

Two water samples, ESMW8A from King Salmon Airport and POMP12S from Pope AFB were recently analyzed for acids and phenols using negative ion chemical ionization (NICI) GC/MS (RSKERL-SOP 177). These samples contained numerous aliphatic carboxylic acids at levels of 1 - 5 ppm and below. The largest peaks among the derivatized acids in both samples have 100% ions at 143 m/z. This ion is expected to be a negative carboxylate ion due to fragmentation of a pentafluorobenzyl ester. These esters could be from branched chain C_8 acids ($C_8H_{15}O_2$), hydroxy-cyclohexyl carboxylic acids ($C_7H_{11}O_3$) or C_7 keto-aliphatic acids ($C_7H_{11}O_3$). Figures 1 and 2 show the total reconstructed NICI chromatogram and extracted ion chromatograms of the 143 m/z ion for these samples. Figure 3 shows the direct comparison of the 143 m/z ions in two samples. Sample POMP12S contains compounds with 143 m/z ions which elute later than compounds in sample ESMW8A. Comparison of the electron impact spectrum of these peaks indicate that the compounds are unique to each sample.

Of the two profiles shown in Figure 3, the Pope AFB sample is unique in that this distribution has not been seen in any of the hundreds of acid-PFB extracts which I have run. The profile of acid-PFB esters shown in the King Salmon sample has been seen in samples from:

Rickenbacken AFB (MW-5)
Patrick AFB (86 MW9D & 86 MW3M2S)
Eglin AFB (80N2B)
Battle Creek (89ESMP2S, 89ESMP10S & BC-3 MW-2)
Hill AFB (82J)

Tracer GC/FTIR Analysis of Samples POMP12S and ESMW8A.

Extremely dry samples are required for GC/FTIR analysis. The samples were taken to dryness using the Savant concentrator. Methylene chloride which was dried over 5A molecular sieve was added to the dried sample. PFB derivative extracts were concentrated by drying 250 µl of extract and adding 100 µl of methylene chloride.

Each PFB extract was injected on the GC/FID side of the Tracer GC before injection into the GC/FTIR side. Identical DB5-MS 30 meter capillary columns with 0.25 mm i.d. and 0.5 µm film thickness were installed in the GC for GC/FID and GC/FTIR analysis. The helium pressure on the GC/FID side was adjusted so that the retention of acetone injected at 150°C matched the retention of acetone in the GC/FTIR side. The column flow in the GC/FTIR side at 150°C was 0.8 ml/min. GC/FID chromatograms of POMP12S and ESMW8A are shown in Figures 4 and 5.

For the Tracer GC/FTIR analysis, 1 - 2 µl of sample was injected splitless for 1 minute. Acquisition of the FTIR spectra was not started until after the solvent peak eluted from the transfer tip. The tip was moved to the lowest vertical position of the trough during solvent elution. The transfer line tip was moved to the slide and acquisition was started when compounds were not eluting from the capiliary column. This time was determined from the GC/FID chromatogram. The slide speed was set to resolve GC peaks separated by 1 second. This allowed the Tracer profile to match the GC/FID and GC/MS profiles. The deposited trace was scanned by averaging 4 scans every second with a resolution of 8 cm^{-1}. Spectra and both Gram-Schmidt and functional group reconstructed chromatograms were processed using peak edit software supplied by Biorad and then transferred via disk to a PC for additional processing and graphic printing.

Figures 6 and 14 show the Gram-Schmidt chromatograms of PFB derivatives of samples POMP12S and ESMW8A obtained from the Bio-

Rad FTS-45 FTIR Spectrometer with GC-Tracer interface. Figures 7-13 and 15-27 are the FTIR spectra of the peaks found in chromatograms of the two samples. Interpretation of these spectra and the electron impact mass spectra gives indications of the character of each compound. While identification cannot be confirmed without analysis of the actual compound, general statements about the nature of the samples can be made.

Peaks which have the 143 m/z ion in the NICI spectra also have absorbances between 3000 and 2800 cm^{-1}. These absorbances correspond to asymmetric and symmetric stretching of CH_3 and CH_2 groups. The relative intensity of absorbances at 2962, 2874 cm^{-1} (asymmetric and symmetric stretching of CH_3) with respect to 2928, 2860 cm^{-1} (asymmetric and symmetric stretching of CH_2) indicate that two or more methyl groups are present in the molecule. The presence of only one carbonyl ester absorption at 1734 cm^{-1} indicates that only one carbonyl is present in the PFB esters. Also the absence of an adsorption near 3300 cm^{-1} shows that the peaks are not PFB esters of hydroxy-cyclohexyl carboxylic acids. The FTIR spectra indicate that the peaks are branched chain aliphatic carboxylic acids PFB esters. Several of the peaks have absorbances at 1470, 1386 and 1366 cm^{-1} which indicate that terminal isopropyl groups are present.

Ten of the twenty-two methylheptanoic, dimethylhexanoic and trimethylpentanoic acid isomers have been purchased or obtained as gifts from researchers. Two branched chain acids are soon coming in from England. Literature searches for the other acids have been unsuccessful. Several small organic synthesis companies have prepared some of these acids in the past. The cost for each acid could be about $500 or more depending on the difficulty in synthesis. If funding is available for commercial synthesis, please let us know. Also, it is possible that simple two step synthetic routes could be done here at RSKERL.

If you should have any questions, please feel free to contact me.

Sincerely,

Dennis D. Fine

Dennis D. Fine

xc: J.L. Seeley
G.B. Smith
R.L. Cosby
J. Wilson
R. L. Staggs(OSU)

MANAGEMENT TECHNOLOGY

Ref: 95-LB57
August 9, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
919 Kerr Research Drive
Ada, OK 74820

THRU: Steve Vandegrift SV

Dear Don:

Please find attached the analytical results for Service Request SF-1-135, King Salmon Airport, requesting the analysis of up to 48 groundwater samples to be analyzed for BTEXXX, TriMBs, TetraMBs, Naphthalene and Total Fuel Carbon. A total of 57 samples were received, most in duplicate, in capped, 40 mL VOA vials on July 31-August 2, 1995. The samples were analyzed on August 2-7, 1995. The samples were stored at 4°C until analyzed. All samples were acquired and processed using the Millennium data system. A 1-500 ppb external calibration curve was used to determine the concentration of the TetraMBs, a 10-500 ppb external calibration curve was used to determine the concentration of Naphthalene, and a 1-1000 ppb external calibration curve was used to determine the concentration of the remaining compounds.

Please note: No duplicates were provided for the following samples "MW-653" and "GP-9". Both samples exceeded the calibration limit for Toluene therefore, a concentration **estimate** is provided for this compound and Total Fuel Carbon. Also, it was determined during analysis that Naphthalene has a 5% carry over rate.

RSKSOP-133 "Simultaneous Analysis of Aromatics and Total Fuel Carbon by Dual Column-Dual Detector for Ground Water Samples" was used for these analyses. Auto-sampling was performed using a Dynatech autosampler in-line with a Tekmar LSC 2000 sample concentrator.

Sincerely,

Lisa R. Black

Lisa R. Black

xc: R.L.Cosby
G.B. Smith
J.T. Wilson
J.L. Seeley JS

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

DP-PT/GC-PID:FID yses for Dr. Kampbell

Units = ng/mL Analy: Black

Sample[redacted]	BENZENE	TOLUENE	ETHYL[redacted]ENE	p-XYLENE	m-XYLENE	o-XYLENE	[redacted],3,5-TriMB
100 ppb	107	106	106	109	106	108	108
QC, OBSERVED, PPB	56.8	55.8	46.3	53.2	52.7	56.5	55.6
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	50.0
MW-10A	6.6	1.2	16.1	30.7	ND	24.3	11.6
MW-10B	ND	ND	ND	ND	ND	ND	ND
MW-50	ND	ND	ND	ND	ND	ND	ND
MW-51	4.7	88.6	49.6	54.7	61.1	40.0	36.5
MW-52	62.6	116	58.8	32.8	38.3	24.4	7.5
MW-88	ND	ND	BLQ	1.5	ND	ND	4.7
MW-89	BLQ	ND	1.8	2.5	2.9	2.4	8.2
MW-90	ND	1.4	BLQ	ND	BLQ	BLQ	ND
MW-92	ND	2.5	ND	ND	BLQ	ND	ND
MW-93	BLQ	5.6	BLQ	0.9	2.2	1.4	ND
10 PPB	10.2	9.9	10.0	10.2	9.9	10.1	10.2
MW-94	ND	BLQ	ND	ND	ND	ND	ND
MW-95	349	1010	90.3	99.0	290	180	33.2
MW-435	28.2	1.4	17.7	31.7	ND	2.2	10.6
MW-460B	BLQ	4.1	BLQ	BLQ	BLQ	BLQ	ND
MW-462C	ND	ND	ND	ND	ND	ND	ND
ESMW-500	BLQ	3.7	47.5	77.8	22.8	20.3	77.6
ESMW-500 Duplicate	BLQ	2.7	45.3	74.7	22.0	19.7	76.5
MW-501	ND	BLQ	BLQ	ND	ND	ND	ND
MW-506	ND	3.1	ND	ND	ND	ND	ND
MW-653	357	* 1420	200	210	559	385	95.7
100 PPB	113	108	107	105	109	106	108
WP-1	12.8	1.2	17.4	21.9	6.4	7.4	4.2
WP-2	3.2	BLQ	ND	BLQ	ND	BLQ	ND
WP-2 Duplicate	3.1	BLQ	ND	BLQ	ND	BLQ	ND
WP-3	1.6	21.3	ND	ND	ND	ND	ND
ESMW-1A	796	5400	399	371	1030	619	86.1
ESMW-1B	BLQ	1.2	ND	ND	BLQ	BLQ	ND
ESMW-2A	ND	0.9	ND	ND	BLQ	ND	ND
ESMW-2B	ND	ND	ND	ND	ND	ND	ND
ESMW-3A	ND	ND	ND	ND	ND	ND	ND
ESMW-4A	ND	ND	ND	ND	ND	ND	ND

* = Estimate of the concentration, no field duplicate provided to make dilutions

ND=None Detected; N/A=Not Analyzed; BLQ=Below Limit of Quantitation, 1ppb for all compounds except Naphthalene which = 10 ppb

Printed 8/9/95 SF-1-135 DP-PT/GC-PID:FID Analyses for Dr. Kampbell Units = ng/mL Analyst: L. Black

SampleName	1,2,4-TriMB	1,2,3-TriMB	1,2,4,5-TetraMB	1,2,3,5-TetraMB	1,2,3,4-TetraMB	Naphthalene	Fuel Carbon
100 ppb	109	109	111	109	114	112	N/A
QC, OBSERVED, PPB	56.9	53.8	54.2	57.3	60.1	58.9	N/A
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	N/A
MW-10A	29.8	24.9	10.4	13.7	21.7	29.6	518
MW-10B	ND	ND	ND	ND	ND	BLQ	BLQ
MW-50	ND	ND	ND	ND	1.1	BLQ	0.9
MW-51	33.7	27.3	17.0	21.4	33.3	60.5	1060
MW-52	1.6	9.5	6.8	12.2	22.8	BLQ	1050
MW-88	1.5	11.5	5.2	12.4	17.7	BLQ	433
MW-89	12.0	14.6	5.1	9.4	12.0	BLQ	388
MW-90	ND	ND	ND	ND	ND	ND	11.8
MW-92	ND	ND	ND	ND	ND	ND	3.2
MW-93	ND	ND	ND	ND	ND	ND	20.2
10 PPB	10.3	10.3	10.2	10.2	10.3	BLQ	N/A
MW-94	ND	ND	ND	ND	ND	ND	BLQ
MW-95	75.2	43.7	3.6	5.0	6.5	25.4	2240
MW-435	23.2	11.0	1.6	2.1	2.4	13.1	241
MW-460B	ND	ND	ND	ND	ND	ND	8.0
MW-462C	ND	ND	ND	ND	ND	ND	ND
ESMW-500	53.5	66.4	38.8	52.7	65.3	49.8	2420
ESMW-500 Duplicate	52.3	63.6	36.2	49.5	62.9	49.1	2070
MW-501	ND	ND	ND	ND	ND	ND	BLQ
MW-506	ND	ND	ND	ND	ND	ND	5.5
MW-653	272	146	17.7	27.2	41.5	127	* 4480
100 PPB	108	107	110	109	111	107	N/A
WP-1	7.9	6.5	4.1	5.2	9.8	18.8	416
WP-2	ND	ND	ND	ND	ND	ND	273
WP-2 Duplicate	ND	ND	ND	ND	ND	ND	336
WP-3	ND	ND	ND	ND	ND	ND	50.9
ESMW-1A	229	133	10.7	17.0	19.6	69.0	8980
ESMW-1B	ND	ND	ND	ND	ND	BLQ	4.8
ESMW-2A	ND	ND	ND	ND	ND	ND	1.2
ESMW-2B	ND	ND	ND	ND	ND	ND	ND
ESMW-3A	ND	ND	ND	ND	ND	ND	ND
ESMW-4A	ND	ND	ND	ND	ND	ND	ND

* = Estimate of the concentration, no field duplicate provided to make dilutions

Printed 8/9/95 SF-1-135

DP-PT/GC-PID:FID Analyses for Dr. Kampbell

Units = ng/mL Analyst: L. Black

SampleName	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TriMB
QC, OBSERVED, PPB	48.5	50.2	53.0	48.6	47.6	51.2	49.7
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	50.0
ESMW-5A	14.3	16.8	7.6	20.4	11.6	14.8	12.2
ESMW-5B	BLQ	ND	0.9	ND	ND	ND	ND
ESMW-6B	ND	ND	ND	ND	ND	ND	ND
ESMW-8A	319	5620	592	368	962	876	161
ESMW-8B	ND	BLQ	BLQ	ND	BLQ	BLQ	ND
ESMW-8B Duplicate	ND	BLQ	BLQ	BLQ	BLQ	BLQ	ND
ESMW-11	ND	1.3	ND	ND	ND	ND	ND
ESMW-12A	3.3	3.8	BLQ	BLQ	ND	ND	ND
ESMW-14	ND	ND	ND	ND	ND	ND	ND
ESMW-15A	BLQ	1.6	27.0	51.4	ND	1.1	79.5
1 PPB	0.9	0.9	0.9	0.9	0.9	0.9	0.9
ESMW-15B	ND	ND	4.8	11.0	ND	ND	6.9
ESMW-16	3.7	ND	1.7	1.6	ND	BLQ	ND
ESMW-16 Duplicate	3.5	ND	1.8	1.6	ND	BLQ	ND
GP-38? NO LABEL	ND	ND	ND	ND	ND	ND	ND
GP-1	ND	ND	ND	ND	ND	ND	ND
GP-2	ND	BLQ	BLQ	BLQ	BLQ	ND	BLQ
GP-4	BLQ	1.3	0.9	1.0	2.0	1.3	ND
GP-5	2.0	4.7	2.9	3.0	7.1	4.5	1.1
GP-6	2.2	1.6	1.0	1.0	2.3	1.5	BLQ
GP-6 Duplicate	2.1	1.5	1.0	1.1	2.4	1.5	BLQ
10 PPB	9.8	9.8	9.9	10.0	10.0	10.0	9.9
GP-7	ND	ND	ND	ND	ND	ND	ND
GP-8	ND	ND	ND	ND	ND	ND	ND
GP-9	1050	* 4150	706	679	1760	880	245
GP-10	ND	ND	ND	ND	ND	ND	ND
EMCON-1	319	755	456	448	1130	698	187
EMCON-2	BLQ	4.1	BLQ	BLQ	BLQ	BLQ	ND
FT01 SW-1	94.8	52.0	44.3	56.6	64.5	40.0	20.5
FT01 SW-02	4.8	3.5	ND	ND	BLQ	ND	ND
U.N. SITE SW-3	ND	ND	ND	ND	ND	ND	ND
U.N. SITE SW-4	ND	BLQ	ND	ND	ND	ND	ND
U.N. SITE SW-05	ND	ND	ND	ND	ND	ND	ND
U.N. SITE SW-06	ND	ND	ND	ND	ND	ND	ND
QC, OBSERVED, PPB	46.7	50.5	52.0	47.1	47.5	50.0	50.0
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	50.0

* = Estim[redacted] of the concentration, no field duplicate provided to make dilut[redacted]

ND=N[redacted] Detected; N/A=Not Analyzed; BLQ=Below Limit of Quantitation, [redacted] for all compounds except Naphthalene which = 10 ppb

DP-PT/GC-PID:FID Analyses for Dr. Kampbell

Units = ng/mL A[redacted]t: L. Black

Sam[redacted]lame	1,2,4-TriMB	1,2,3-TriMB	1,2,4,5[redacted]B	1,2,3,5-TetraMB	1,2,3,4-TetraMB	Naphthalene	[redacted]Carbon
QC, OBSERVED, PPB	50.4	47.3	45.5	48.3	49.2	42.8	N/A
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	N/A
ESMW-5A	22.1	11.4	2.7	3.3	4.4	21.3	275
ESMW-5B	ND	ND	ND	ND	ND	ND	1.3
ESMW-6B	ND	ND	ND	ND	ND	ND	N/A
ESMW-8A	470	398	25.6	65.6	129	225	13330
ESMW-8B	ND	BLQ	2.1	1.6	24.6	ND	94.7
ESMW-8B Duplicate	ND	BLQ	2.1	1.6	24.2	ND	99.7
ESMW-11	ND	ND	ND	ND	ND	ND	1.1
ESMW-12A	ND	ND	ND	ND	ND	BLQ	63.2
ESMW-14	ND	ND	ND	ND	ND	ND	ND
ESMW-15A	ND	27.9	27.1	39.2	52.0	73.8	1670
1 PPB	1.2	1.0	1.0	0.9	1.0	N/A	N/A
ESMW-15B	ND	12.9	15.7	17.9	37.8	30.6	552
ESMW-16	BLQ	ND	ND	ND	ND	ND	21.0
ESMW-16 Duplicate	1.3	1.1	1.8	1.9	3.1	BLQ	37.4
NO LABEL	ND	ND	ND	BLQ	1.6	BLQ	6.9
GP-1	ND	ND	ND	ND	ND	ND	ND
GP-2	ND	ND	ND	ND	ND	ND	BLQ
GP-4	1.0	ND	ND	ND	ND	ND	8.5
GP-5	3.4	1.2	ND	ND	ND	ND	37.3
GP-6	1.1	ND	ND	ND	ND	ND	24.7
GP-6 Duplicate	1.3	BLQ	ND	1.2	1.8	BLQ	34.0
10 PPB	10.1	10.1	10.3	10.3	11.2	12.8	N/A
GP-7	ND	ND	ND	ND	ND	ND	ND
GP-8	ND	ND	ND	ND	ND	ND	ND
GP-9	795	263	35.0	55.9	78.5	366	* 12800
GP-10	ND	ND	ND	ND	ND	ND	ND
EMCON-1 – FTol-FD9	556	209	26.8	42.7	60.2	230	6680
EMCON-2 FTol-FD8	ND	ND	ND	ND	ND	ND	5.8
FT01 SW-1	24.7	16.3	8.0	10.7	15.6	21.6	772
FT01 SW-02	ND	ND	ND	ND	ND	BLQ	7.6
U.N. SITE SW-3	ND	ND	ND	ND	ND	ND	ND
U.N. SITE SW-4	ND	ND	ND	ND	ND	ND	BLQ
U.N. SITE SW-05	ND	ND	ND	ND	ND	ND	ND
U.N. SITE SW-06	ND	ND	ND	ND	ND	ND	ND
QC, OBSERVED, PPB	49.5	45.9	44.2	47.1	47.2	41.9	N/A
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	N/A

* = Estimate of the concentration, no field duplicate provided to make dilutions

ND=None Detected; N/A=Not Analyzed; BLQ=Below Limit of Quantitation, 1ppb for all compounds except Naphthalene which = 10 ppb

MANAGEMENT TECHNOLOGY

Ref: 95-DF42

Aug 23, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

King Salmon

Dear Don:

This letter reports the first successful analysis of samples on the Bio-Rad Tracer GC/FTIR at RSKERL. Louis Staggs' and my efforts began last July with a trip to Conoco to run samples on their Tracer. Since then we experienced first hand the difficulties of bringing up a system which had been idle for over four years. We returned a MCT detector for re-evacuation of its Dewar, installed a new CO_2 trap system to minimize CO_2 background fluctuations in the purge gas, replaced an cracked ion gauge which was causing poor vacuum, modified an expansion loop in the GC and a connecting spacer between the xyz positioning platform and the transfer line block and installed a new transfer line. We now can align the tip and meet specifications for tip alignment without assistance from a service engineer.

Preliminary GC/MS Analysis

Two water samples, ESMW8A from King Salmon Airport and POMP12S from Pope AFB were recently analyzed for acids and phenols using negative ion chemical ionization (NICI) GC/MS (RSKERL-SOP 177). These samples contained numerous aliphatic carboxylic acids at levels of 1 - 5 ppm and below. The largest peaks among the derivatized acids in both samples have 100% ions at 143 m/z. This ion is expected to be a negative carboxylate ion due to fragmentation of a pentafluorobenzyl ester. These esters could be from branched chain C_8 acids ($C_8H_{15}O_2$), hydroxy-cyclohexyl carboxylic acids ($C_7H_{11}O_3$) or C_7 keto-aliphatic acids ($C_7H_{11}O_3$). Figures 1 and 2 show the total reconstructed NICI chromatogram and extracted ion chromatograms of the 143 m/z ion for these samples. Figure 3 shows the direct comparison of the 143 m/z ions in two samples. Sample POMP12S contains compounds with 143 m/z ions which elute later than compounds in sample ESMW8A. Comparison of the electron impact spectrum of these peaks indicate that the compounds are unique to each sample.

Of the two profiles shown in Figure 3, the Pope AFB sample is unique in that this distribution has not been seen in any of the hundreds of acid-PFB extracts which I have run. The profile of acid-PFB esters shown in the King Salmon sample has been seen in samples from:

Rickenbacken AFB (MW-5)
Patrick AFB (86 MW9D & 86 MW3M2S)
Eglin AFB (80N2B)
Battle Creek (89ESMP2S, 89ESMP10S & BC-3 MW-2)
Hill AFB (82J)

Tracer GC/FTIR Analysis of Samples POMP12S and ESMW8A.

Extremely dry samples are required for GC/FTIR analysis. The samples were taken to dryness using the Savant concentrator. Methylene chloride which was dried over 5A molecular sieve was added to the dried sample. PFB derivative extracts were concentrated by drying 250 µl of extract and adding 100 µl of methylene chloride.

Each PFB extract was injected on the GC/FID side of the Tracer GC before injection into the GC/FTIR side. Identical DB5-MS 30 meter capillary columns with 0.25 mm i.d. and 0.5 µm film thickness were installed in the GC for GC/FID and GC/FTIR analysis. The helium pressure on the GC/FID side was adjusted so that the retention of acetone injected at 150°C matched the retention of acetone in the GC/FTIR side. The column flow in the GC/FTIR side at 150°C was 0.8 ml/min. GC/FID chromatograms of POMP12S and ESMW8A are shown in Figures 4 and 5.

For the Tracer GC/FTIR analysis, 1 - 2 µl of sample was injected splitless for 1 minute. Acquisition of the FTIR spectra was not started until after the solvent peak eluted from the transfer tip. The tip was moved to the lowest vertical position of the trough during solvent elution. The transfer line tip was moved to the slide and acquisition was started when compounds were not eluting from the capillary column. This time was determined from the GC/FID chromatogram. The slide speed was set to resolve GC peaks separated by 1 second. This allowed the Tracer profile to match the GC/FID and GC/MS profiles. The deposited trace was scanned by averaging 4 scans every second with a resolution of 8 cm^{-1}. Spectra and both Gram-Schmidt and functional group reconstructed chromatograms were processed using peak edit software supplied by Biorad and then transferred via disk to a PC for additional processing and graphic printing.

Figures 6 and 14 show the Gram-Schmidt chromatograms of PFB derivatives of samples POMP12S and ESMW8A obtained from the Bio-

Rad FTS-45 FTIR Spectrometer with GC-Tracer interface. Figures 7-13 and 15-27 are the FTIR spectra of the peaks found in chromatograms of the two samples. Interpretation of these spectra and the electron impact mass spectra gives indications of the character of each compound. While identification cannot be confirmed without analysis of the actual compound, general statements about the nature of the samples can be made.

Peaks which have the 143 m/z ion in the NICI spectra also have absorbances between 3000 and 2800 cm^{-1}. These absorbances correspond to asymmetric and symmetric stretching of CH_3 and CH_2 groups. The relative intensity of absorbances at 2962, 2874 cm^{-1} (asymmetric and symmetric stretching of CH_3) with respect to 2928, 2860 cm^{-1} (asymmetric and symmetric stretching of CH_2) indicate that two or more methyl groups are present in the molecule. The presence of only one carbonyl ester absorption at 1734 cm^{-1} indicates that only one carbonyl is present in the PFB esters. Also the absence of an adsorption near 3300 cm^{-1} shows that the peaks are not PFB esters of hydroxy-cyclohexyl carboxylic acids. The FTIR spectra indicate that the peaks are branched chain aliphatic carboxylic acids PFB esters. Several of the peaks have absorbances at 1470, 1386 and 1366 cm^{-1} which indicate that terminal isopropyl groups are present.

Ten of the twenty-two methylheptanoic, dimethylhexanoic and trimethylpentanoic acid isomers have been purchased or obtained as gifts from researchers. Two branched chain acids are soon coming in from England. Literature searches for the other acids have been unsuccessful. Several small organic synthesis companies have prepared some of these acids in the past. The cost for each acid could be about $500 or more depending on the difficulty in synthesis. If funding is available for commercial synthesis, please let us know. Also, it is possible that simple two step synthetic routes could be done here at RSKERL.

If you should have any questions, please feel free to contact me.

Sincerely,

Dennis D. Fine

Dennis D. Fine

xc: J.L. Seeley
G.B. Smith
R.L. Cosby
J. Wilson
R. L. Staggs(OSU)

MANTECH

Ref: 95-DF45

Aug. 10, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

As requested in Service Request SF-1-135, GC/MS analysis for phenols and aliphatic/aromatic acids was done on three water samples, ESMW15B, MW95 and ESMW8A from King Salmon Airport. Derivatization of the samples were done by Amy Zhao on August 1, 1995. Twenty-five ml of sample ESMW8A was diluted with 75 ml of acid free water before extraction. This was necessary because the capillary column was overloaded by compounds in the PFB extract. The extracts were analyzed by GC/MS on August 2, 1995. RSKERL SOP 177 was used for the extraction, derivatization and GC/MS analysis of the samples.

Table I provides the concentrations of the phenols and aliphatic/aromatic acids found in the King Salmon Airport samples and quality assurance samples run at the same time as the samples. Spike recoveries for each of the acids and phenols were determined in a 50 ppb spike of 100 ml of water blank. Recovery of the 50 ppb concentration was poor for low molecular weight aliphatic acids due to the poor extraction efficiencies of these acids from water. Higher molecular weight aliphatic and aromatic acids exhibit good recoveries.

Three chromatograms of the PFB extracts of sample ESMW8A are provided to show the column overload. Figure 1 shows the chromatogram of the PFB extract from the undiluted water sample. The column is overloaded by trimethylacetic acid-PFB, 3,3-dimethylbutyric acid-PFB and PFB derivatives which have the 143 m/z ion. Figure 2 shows the chromatogram of the 1/4 dilution of the sample. Here the overloading is less. When this extract is injected under split flow of 20 ml/min (See Figure 3), the overload is diminished considerably.

The familiar pattern of peaks with 143 m/z ions are again present in the chromatogram of ESMW8A and are displayed in Figure 4. This sample contained the highest levels of these compounds found in any sample to date. This sample is presently being

analyzed by the Tracer GC/FTIR. Preliminary evaluation of the FTIR spectra indicates that the peaks are aliphatic esters. Confirmed identification of the compounds will be attempted as soon as authentic compounds become available. Eight branched chain C_8 aliphatic acids have been located as a result of our literature search.

If you should have any questions, please feel free to contact me.

Sincerely,

Dennis D. Fine

Dennis D. Fine

xc: J.L. Seeley
G.B. Smith
R.L. Cosby

Table I. Quantitative Report and QC Data for Phenols and Aliphatic and Aromatic Acids for Sample from MW-3 at KL Avenue Landfill, Kalamazoo, MI (Service Request SF-1-148).

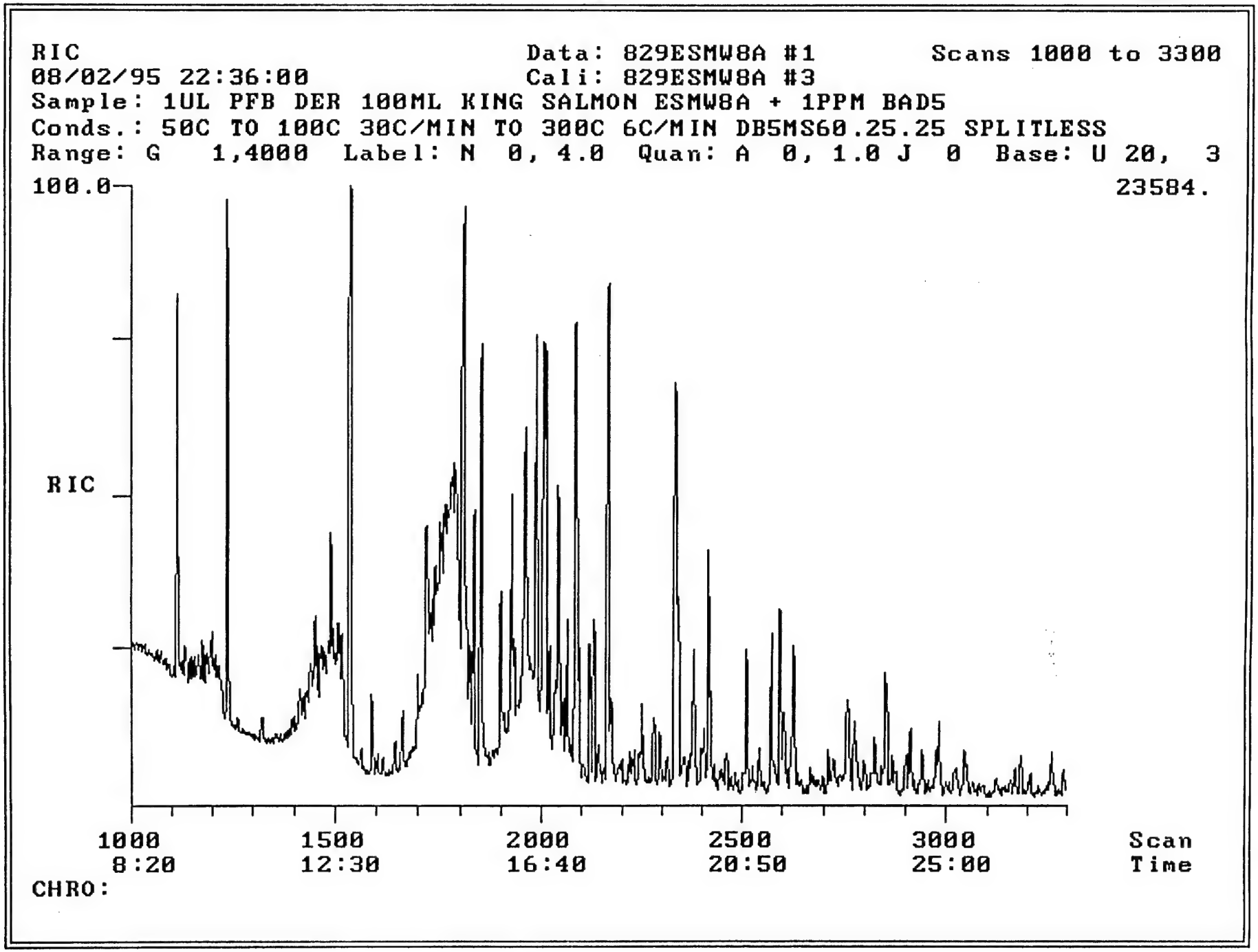
Concentration ppb

		ESMW-15B	MW95	ESMW-8A	Derivative Standard Blank	Extraction Blank	50 ppb Extraction Recovery	10ppb Check Standard	100ppb Check Standard
1	PROPANOIC ACID - PFB	***	11	389	***	***	6	8	88
2	2-METHYLPROPANOIC ACID - PFB	***	***	30	***	***	18	8	87
3	TRIMETHYL ACETIC ACID - PFB	***	8	720	***	***	47	9	82
4	BUTYRIC ACID - PFB	***	***	47	***	***	15	6	86
5	2-METHYLBUTYRIC ACID - PFB	***	***	24	***	***	42	9	86
6	3-METHYLBUTYRIC ACID - PFB	***	6	19	***	***	40	8	86
7	3,3-DIMETHYLBUTYRIC ACID - PFB	5	15	(1510)*	N.F.	***	55	9	93
8	PENTANOIC ACID - PFB	***	***	25	***	***	44	8	84
9	2,3-DIMETHYLBUTYRIC ACID - PFB	***	***	75	N.F.	N.F.	54	9	90
10	2-ETHYLBUTYRIC ACID - PFB	***	***	18	N.F.	N.F.	55	9	82
11	2-METHYLPENTANOIC ACID - PFB	***	***	19	N.F.	***	56	8	89
12	3-METHYLPENTANOIC ACID - PFB	***	N.F.	54	***	***	55	9	86
13	4-METHYLPENTANOIC ACID - PFB	***	***	29	N.F.	***	55	8	79
14	HEXANOIC ACID - PFB	5	5	10	***	9	61	9	84
15	2-METHYLHEXANOIC ACID - PFB	***	N.F.	N.F.	N.F.	***	59	7	88
16	PHENOL - PFB	***	***	20	***	***	78	6	91
17	CYCLOPENTANECARBOXYLIC ACID - PFB	***	***	50	N.F.	N.F.	46	8	85
18	5-METHYLHEXANOIC ACID - PFB	N.F.	***	44	N.F.	***	56	13	137
19	o-CRESOL - PFB	***	***	9	***	***	57	9	92
20	2-ETHYLHEXANOIC ACID - PFB	***	8	189	***	***	59	7	85
21	HEPTANOIC ACID - PFB	***	***	23	N.F.	6	58	8	85
22	m-CRESOL - PFB	***	***	14	N.F.	***	59	9	94
23	p-CRESOL - PFB	***	***	33	N.F.	***	57	9	96
24	1-CYCLOPENTENE-1-CARBOXYLIC ACID - PFB	***	***	5	N.F.	***	42	8	85
25	o-ETHYLPHENOL - PFB	N.F.	N.F.	N.F.	N.F.	N.F.	58	10	99
26	CYCLOPENTANEACETIC ACID - PFB	N.F.	***	13	N.F.	N.F.	57	11	91
27	2,6-DIMETHYLPHENOL - PFB	N.F.	N.F.	12	N.F.	N.F.	51	10	97
28	2,5-DIMETHYLPHENOL - PFB	N.F.	***	10	N.F.	N.F.	61	9	95
29	CYCLOHEXANECARBOXYLIC ACID - PFB	***	***	34	N.F.	N.F.	58	9	91
30	3-CYCLOHEXENE-1-CARBOXYLIC ACID - PFB	***	***	N.F.	***	***	52	10	90
31	2,4-DIMETHYLPHENOL - PFB	N.F.	***	N.F.	N.F.	N.F.	47	10	98
32	3,5-DIMETHYLPHENOL & M-ETHYLPHENOL - PFB	N.F.	N.F.	7	N.F.	N.F.	59	9	96
33	OCTANOIC ACID - PFB	***	5	30	***	9	64	8	82
34	2,3-DIMETHYLPHENOL - PFB	N.F.	***	N.F.	N.F.	N.F.	57	10	96
35	p-ETHYLPHENOL - PFB	N.F.	N.F.	N.F.	N.F.	N.F.	58	10	99
36	BENZOIC ACID - PFB	***	14	199	***	5	60	8	87
37	3,4-DIMETHYLPHENOL - PFB	N.F.	***	10	N.F.	N.F.	61	9	95
38	m-METHYLBENZOIC ACID - PFB	***	55	528	N.F.	N.F.	50	9	85
39	1-CYCLOHEXENE-1-CARBOXYLIC ACID - PFB	***	N.F.	7	N.F.	N.F.	55	9	86
40	CYCLOHEXANEACETIC ACID - PFB	N.F.	***	18	N.F.	N.F.	60	8	90
41	2-PHENYLPROPANOIC ACID - PFB	N.F.	***	13	N.F.	N.F.	57	9	88
42	o-METHYLBENZOIC ACID - PFB	***	15	203	***	***	62	9	92
43	PHENYLACETIC ACID - PFB	***	11	278	***	***	59	8	88
44	m-TOLYLACETIC ACID - PFB	N.F.	18	572	N.F.	N.F.	51	9	90
45	o-TOLYLACETIC ACID - PFB	N.F.	7	229	N.F.	N.F.	58	9	84
46	2,6-DIMETHYLBENZOIC ACID - PFB	***	***	22	N.F.	N.F.	58	13	103
47	p-TOLYLACETIC ACID - PFB	***	17	329	N.F.	N.F.	61	11	97
48	p-METHYLBENZOIC ACID - PFB	***	7	240	N.F.	***	60	9	89
49	3-PHENYLPROPANOIC ACID - PFB	N.F.	***	16	N.F.	N.F.	62	8	91
50	2,5-DIMETHYLBENZOIC ACID - PFB	N.F.	5	66	N.F.	N.F.	61	9	91
51	DECANOIC ACID - PFB	***	***	17	***	***	62	8	84
52	2,4-DIMETHYLBENZOIC ACID - PFB	***	***	32	N.F.	N.F.	62	9	90
53	3,5-DIMETHYLBENZOIC ACID - PFB	N.F.	N.F.	19	N.F.	N.F.	51	8	85
54	2,3-DIMETHYLBENZOIC ACID - PFB	N.F.	***	25	N.F.	N.F.	64	9	93
55	4-ETHYLBENZOIC ACID - PFB	***	***	298	N.F.	N.F.	59	9	87
56	2,4,6-TRIMETHYLBENZOIC ACID - PFB	***	10	207	N.F.	N.F.	67	10	102
57	3,4-DIMETHYLBENZOIC ACID - PFB	***	***	116	N.F.	N.F.	59	9	84
58	2,4,5-TRIMETHYLBENZOIC ACID - PFB	N.F.	5	29	N.F.	N.F.	62	10	91

* Indicates concentration was above highest calibration standard (1ppm).

*** Indicates concentration of extract was below lowest calibration standard (5 ppb).

N.F. Indicates not found.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08/02/95 22:36:00
Cali: 829ESMW8A #3
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Conds.: 50C TO 100C 30C/MIN TO 300C 6C/MIN DB5MS60.25.25 SPLITLESS
Range: G 1,4000 Label: N 0, 4.0 Quan: A 0, 1.0 J 0 Base: U 20, 3
100.0
23584.
RIC
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12:30
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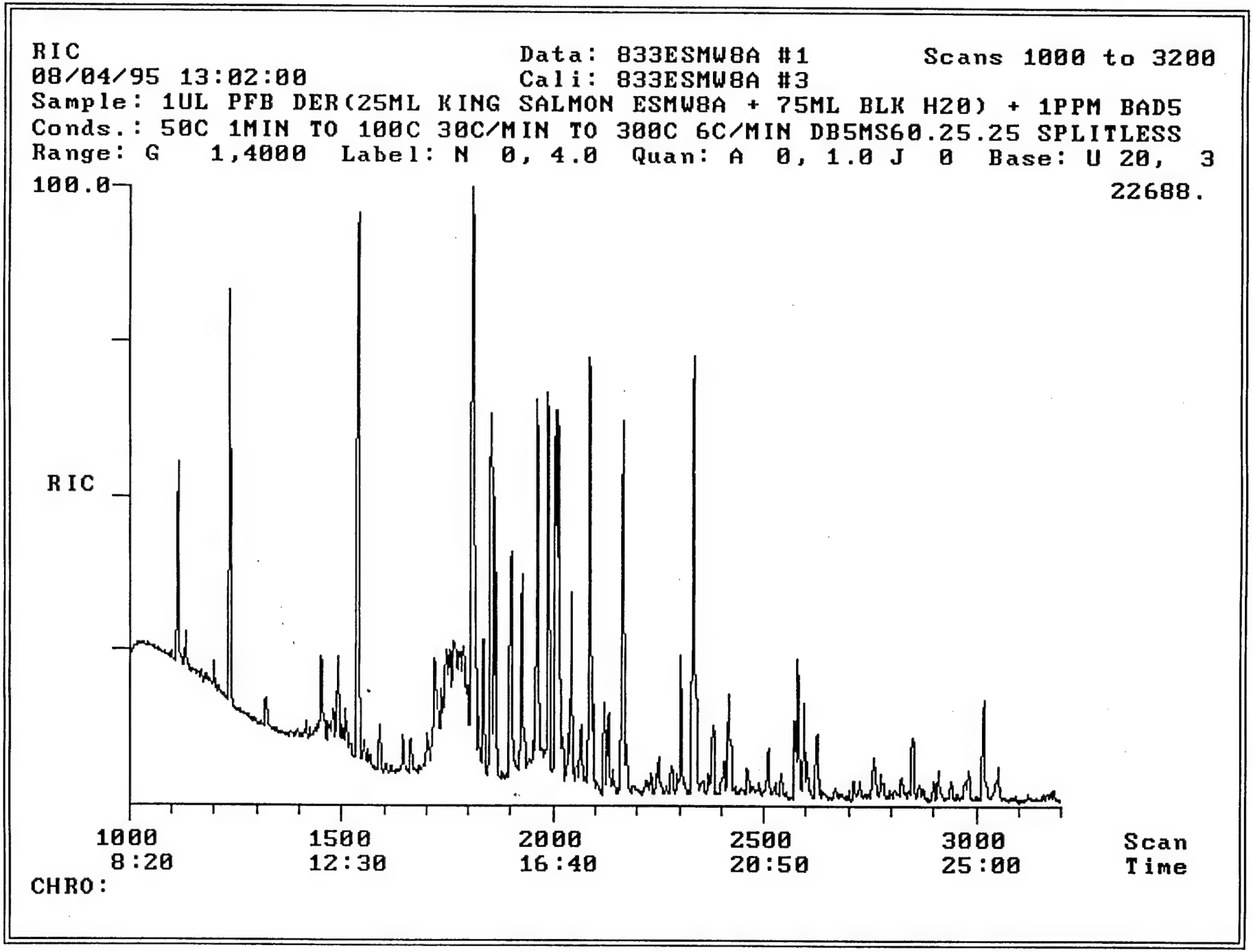
2500
20:50
3000
25:00
Scan
Time
CHRO:

Figure 1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08/04/95 13:02:00
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Cali: 833ESMW8A #3
Scans 1000 to 3200
Sample: 1UL PFB DER(25ML KING SALMON ESMW8A + 75ML BLK H20) + 1PPM BAD5
Conds.: 50C 1MIN TO 100C 30C/MIN TO 300C 6C/MIN DB5MS60.25.25 SPLITLESS
Range: G 1,4000 Label: N 0, 4.0 Quan: A 0, 1.0 J 0 Base: U 20, 3
100.0
22688.
RIC
1000
8:20
1500
12:30
2000
16:40
2500
20:50
3000
25:00
Scan
Time
CHRO:

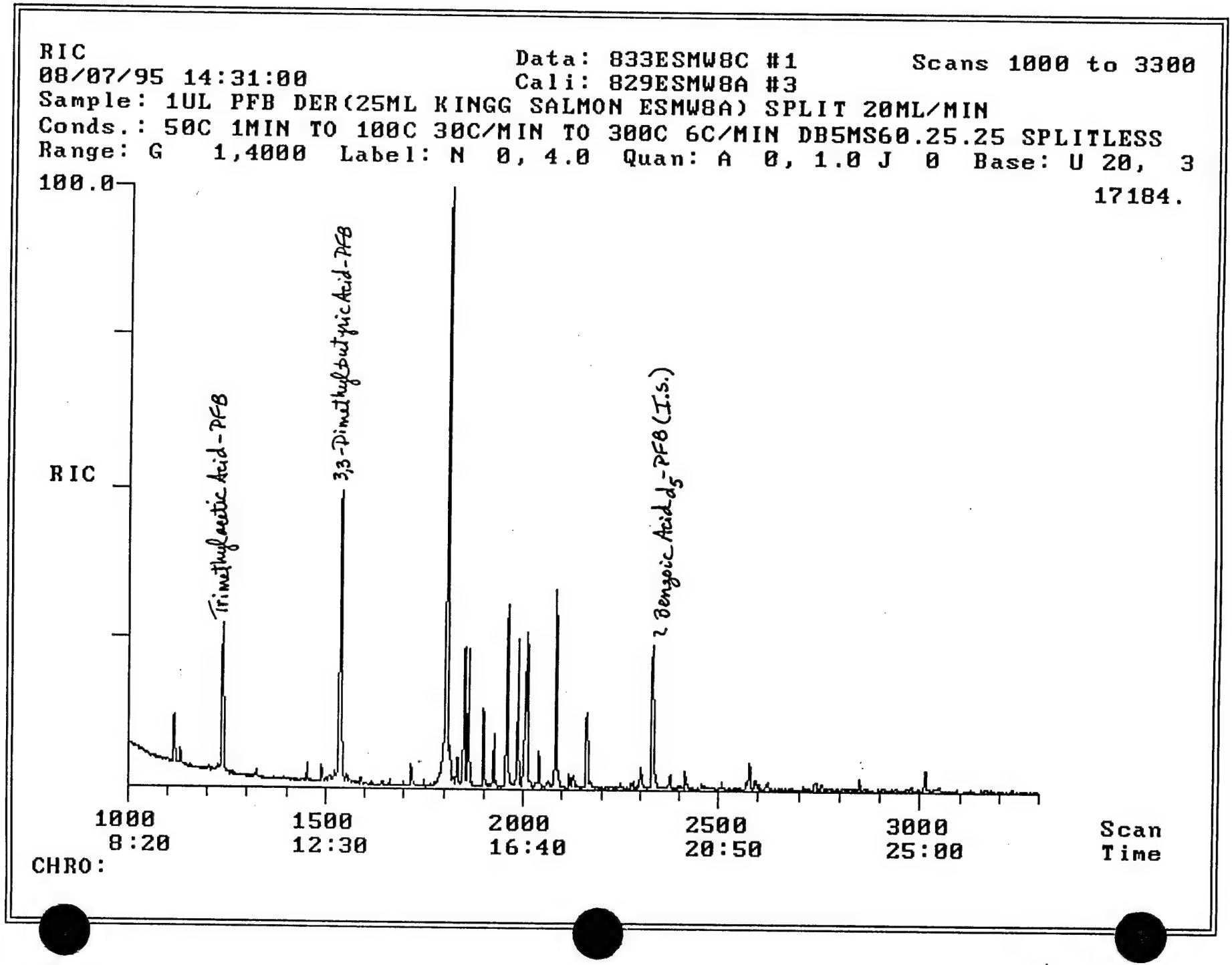

RIC
08/07/95 14:31:00
Data: 833ESMW8C #1
Cali: 829ESMW8A #3
Scans 1000 to 3300
Sample: 1UL PFB DER(25ML KINGG SALMON ESMW8A) SPLIT 20ML/MIN
Conds.: 50C 1MIN TO 100C 30C/MIN TO 300C 6C/MIN DB5MS60.25.25 SPLITLESS
Range: G 1,4000 Label: N 0, 4.0 Quan: A 0, 1.0 J 0 Base: U 20, 3
100.0
17184.
RIC
Trimethylacetic Acid-PFB
3,3-Dimethylbutyric Acid-PFB
2 Benzoic Acid d_5-PFB (I.S.)
1000
8:20
1500
12:30
2000
16:40
2500
20:50
3000
25:00
Scan
Time
CHRO:

Figure 3

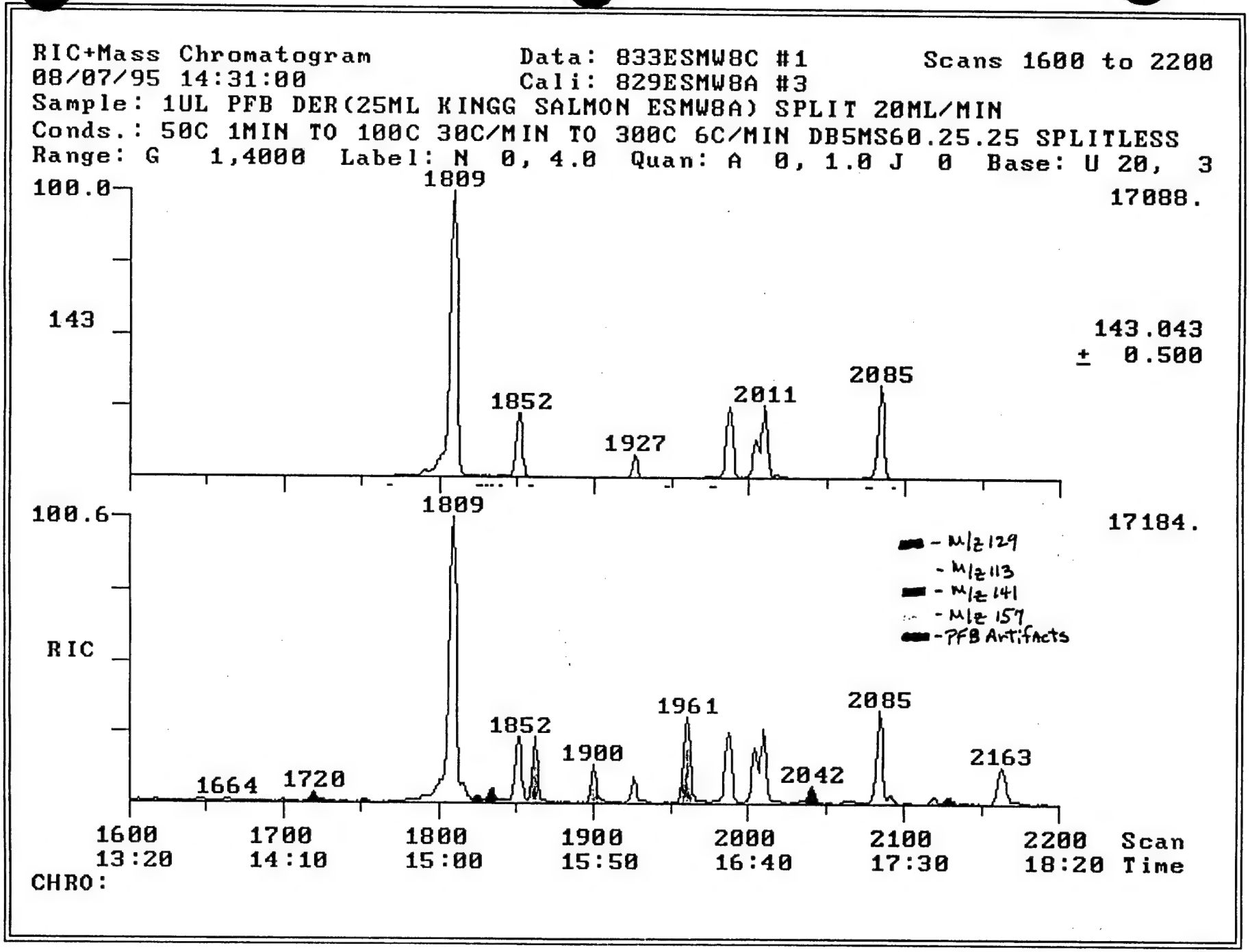

RIC+Mass Chromatogram
08/07/95 14:31:00
Data: 833ESMW8C #1
Cali: 829ESMW8A #3
Scans 1600 to 2200
Sample: 1UL PFB DER(25ML KINGG SALMON ESMW8A) SPLIT 20ML/MIN
Conds.: 50C 1MIN TO 100C 30C/MIN TO 300C 6C/MIN DB5MS60.25.25 SPLITLESS
Range: G 1,4000 Label: N 0, 4.0 Quan: A 0, 1.0 J 0 Base: U 20, 3
100.0
143
1809
1852
1927
2011
2085
17088.
143.043
± 0.500
100.6
RIC
1809
1664
1720
1852
1900
1961
2042
2085
2163
17184.
M/z 129
M/z 113
M/z 141
M/z 157
PFB Artifacts
1600 1700 1800 1900 2000 2100 2200 Scan
13:20 14:10 15:00 15:50 16:40 17:30 18:20 Time
CHRO:

Figure 4

MANAGEMENT TECHNOLOGY

Ref: 95-TH61/vg
95-BS2/vg

August 7, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

Attached are the results of 51 field samples for pH, Redox, CO_2, Ferrous Iron, Total Alkalinity, Dissolved Oxygen, Temperature, and Monitoring Well depth from the top of casing as per Service Request #SFTA-1-58. Samples were analyzed July 24, 25, 26, 27, and 28, 1995.

Please note that samples with greater than 5.0 mg/l Ferrous Iron may have interfered with the Hach carbon dioxide color test. If you have any questions concerning these results, please feel free to contact us.

Sincerely,

Tim Hensley

Tim Hensley

Brad Scroggins

Brad Scroggins TS

xc: R.L. Cosby
J.L. Seeley
G.B. Smith

King Salmon AFB

Sample	Total Alkalinity mg/L	Ferrous Iron mg/L	CO_2 mg/L	Redox	pH	D.O. mg/L	Temp °C
KSMW-653	47.6	5.0	55.0	65.0	6.95	2.9	5.4
ESMW-2A	54.4	<.1	35.0	240	6.72	5.1	4.6
ESMW-2B	54.4	<.1	50.0	230	6.50	.4	5.5
ESMW-4A	68.0	<.1	90.0	250	6.52	5.2	4.8
ESMW-1A	81.6	3.0	40.0	35.0	6.81	1.4	4.9
ESMW-1B	68.0	<.1	25.0	150	6.85	2.0	4.6
ESMW-3A	47.6	<.1	30.0	235	6.61	1.4	7.1
ESMW-5A	81.6	<.1	45.0	230	6.73	1.4	8.0
ESMW-5B	74.8	<.1	15.0	200	7.38	0.3	7.0
MW-460B	81.6	<.1	30.0	260	6.62	3.6	5.0
ESMW-6B	54.4	<.1	30.0	250	6.61	0.4	7.6
MW-95	74.8	3.0	35.0	15.0	6.72	0.4	6.1
MW-462-C	40.8	<.1	35.0	145	6.91	1.0	10.0
MW-93	34.0	<.1	30.0	220	6.50	2.5	4.6
MW-435	74.8	<.1	20.0	205	7.19	1.8	5.4
MW-50	40.8	<.1	35.0	245	6.53	11.3	4.3
ESMW-15A	143	25.0	120	-15.0	6.63	0.4	4.8
ESMW-15B	88.4	.25	20.0	5.0	7.01	1.4	5.0
MW-52	95.2	5.0	30.0	-15.0	7.05	2.7	6.5
ESMW-8A	340	40.0	>210	-45.0	6.59	0.1	5.4
ESMW-8B	74.8	.10	10.0	-90.0	7.55	0.2	6.5
MW-501	47.6	<.1	5.0	225	6.49	8.0	4.9
MW-88	54.4	3.0	35.0	85.0	6.73	3.5	4.4
MW-88 Dup	54.4	3.0	35.0	80.0	6.68	----	----
MW-51	116	10.0	90.0	-50.0	6.69	0.5	4.2
MW-500	136	10.0	85.0	-75.0	6.84	0.3	5.1
MW-89	47.6	<.1	25.0	16.5	6.77	0.3	4.9
MW-506	47.6	<.1	5.0	-55.0	7.70	0.3	5.5
MW-90	40.8	<.1	20.0	185	6.86	12.6	4.0
ESMW-10A	109	5.0	55.0	-10.0	6.77	0.6	4.5
ESMW-10B	68.0	<.1	15.0	75.0	7.13	6.9	3.2
ESMW-14	27.2	<.1	55.0	255	6.21	2.4	2.9
ESMW-16	109	25.0	130	-15.0	6.60	0.8	2.1
ESMW-16 Dup	116	25.0	135	-15.0	6.63	----	----

Sample	Total Alkalinity	Ferrous Iron	CO_2	Redox	pH	D.O.	Temp °C
ESMW-12A	112	20.0	125	10.0	6.80	0.2	5.3
WP-1	95.2	10.0	75.0	-10.0	6.74	0.7	3.6
WP-2	102	15.0	175	60.0	6.26	1.6	3.7
WP-3	88.4	45.0	265	40.0	6.13	1.7	7.2
MW-94	40.8	<.1	20.0	125	6.92	0.8	5.7
ESMW-11 Surface	N/A	1.0	N/A	35.0	N/A	2.5	13.6
GP-10	102	<.1	90.0	240	6.33	0.4	5.1
GP-1	81.6	<.1	75.0	225	6.36	2.2	5.3
GP-7	74.8	2.50	70.0	145	6.37	0.7	2.5
EMCON-1	177	5.0	70.0	-35.0	6.92	0.5	4.5
GP-2	40.8	<.1	25.0	95.0	6.61	9.9	4.6
GP-3	54.4	<.1	25.0	165	6.83	5.8	4.4
GP-5	40.8	<.1	30.0	155	6.45	N/A	N/A
GP-8	27.2	<.1	30.0	100	6.46	0.0	5.5
GP-8 Dup	27.2	<.1	30.0	95.0	6.48	----	----
GP-6	61.2	<.1	15.0	90.0	7.02	0.8	4.9
GP-9	23.1	15.0	105	-65.0	6.78	0.5	5.9
GP-4	40.8	<.1	30.0	200	6.72	10.4	6.1
EMCON-2	54.4	<.1	55.0	200	6.42	6.0	5.5
MW-92	47.6	<.1	35.0	220	6.58	2.6	4.3

King Salmon
Monitoring Well Water Level

Well	TOC ft.
ESMW-15A	15.00
ESMW-15B	14.90
MW-52	4.32
MW-89	10.58
MW-90	17.33
MW-500	13.30
ESMW-8A	9.92
ESMW-8B	9.80
MW-51	10.38
MW-88	12.95
MW-501	17.72
ESMW-10A	3.94
ESMW-10B	3.63
MW-50	10.54
MW-506	3.30
ESMW-12A	G.L.
ESMW-13A	5.25
ESMW-14	7.71
MW-92C	17.92
EMCON-1	7.98
EMCON-2	11.71
MW-93	12.86
MW-94	13.12
MW-95	13.86
ESMW-13A	15.70
ESMW-2B	17.00
ESMW-2A	17.04
ESMW-4A	16.95
ESMW-4B	16.93
ESMW-5A	8.16
ESMW-5B	8.54
MW-460B	15.72
ESMW-6B	9.14
MW-462C	6.68
MW-435	19.50
MW-653	13.34

MANAGEMENT TECHNOLOGY

Ref: 95-LP110/vg
95-TH63/vg
95-BS3/vg

August 8, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

Attached are inorganic results for two sets of samples from King Salmon AFB, Alaska submitted to MERSC July 31, 1995 as a part of Service Request #SF-1-135. The samples were analyzed July 31 through August 3 using EPA Methods 353.1, 120.1 and Waters capillary electrophoresis Method N-601.

Blanks, spikes, duplicates, and known AQC samples were analyzed along with your samples for quality control. If you have any questions concerning this data, please feel free to contact us.

Sincerely,

Lynda Pennington
Lynda Pennington

Tim Hensley
Tim Hensley

Brad Scroggins
Brad Scroggins by LKP

xc: R.L. Cosby
J.L. Seeley JLS
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

FT01

Sample	mg/L Cl^-	mg/L $SO_4^=$	mg/L $NO_2^-+NO_3^-(N)$	µS/cm Conductivity
ESMW-1A	2.07	1.39	<.05	161
ESMW-1B	3.47	3.71	0.25	134
ESMW-2A	2.42	4.80	1.38	117
ESMW-2B	3.04	3.13	0.38	113
ESMW-3A	3.70	0.97	<.05	100
ESMW-4A	3.99	3.16	2.52	157
ESMW-5A	3.59	2.33	<.05	162
ESMW-5A Dup	3.64	2.34	----	---
ESMW-5B	3.43	2.20	<.05	146
ESMW-5B Dup	----	----	<.05	147
ESMW-6B	2.44	1.52	<.05	87
ESMW-15A	3.32	0.51	<.05	186
ESMW-15B	3.96	1.98	<.05	172
MW-50	3.64	1.48	0.19	90
MW-93	3.39	2.77	0.13	70
MW-95	3.30	1.60	<.05	116
MW-435	2.53	1.01	0.11	141
MW-435 Dup	2.50	1.06	----	---
MW-460B	2.78	5.85	0.79	161
MW-460B Dup	----	----	0.79	160
MW-462C	2.65	0.94	0.13	78
KSMW-653	3.17	2.90	0.34	181
EM CON-1	3.38	<.50	<.05	323
EM CON-1 Dup	----	----	----	323
EM CON-2	6.02	2.91	2.21	150
WP-1	4.08	<.50	<.05	155
ESMW-8A	5.67	<.50	<.05	521
ESMW-8B	2.90	1.23	<.05	144
ESMW-8B Dup	2.88	1.18	----	---
ESMW-12A	4.47	<.50	<.05	79
ESMW-14	2.39	3.16	<.05	58
ESMW-16	4.82	1.38	<.05	173
MW-10A	4.19	2.79	<.05	191
MW-10B	3.99	2.95	<.05	120
MW-10B Dup	----	----	<.05	---
MW-51	2.94	2.49	<.05	164
MW-52	2.45	1.16	<.05	177
MW-52 Dup	2.56	1.19	----	---
MW-88	4.58	3.84	<.05	113
MW-89	3.63	2.69	<.05	94
MW-90	3.29	2.23	<.05	77
MW-92	2.81	3.61	1.07	104
MW-92 Dup	----	----	----	104
MW-94	2.51	1.61	<.05	74
MW-94 Dup	----	----	<.05	---
MW-500	3.30	2.43	<.05	220
MW-501	2.26	4.07	<.05	104
MW-506	4.15	13.1	<.05	117
MW-506 Dup	4.27	13.0	----	---
GP-1	4.17	1.89	2.41	172
GP-2	2.15	<.50	1.41	75

Sample	mg/L Cl^-	mg/L $SO_4^=$	mg/L $NO^-_2+NO^-_3(N)$	µS/cm Conductivity
GP-3	3.19	1.67	.80	120
GP-4	3.77	1.29	1.05	107
GP-5	3.81	3.01	.89	89
GP-5 Dup	----	----	.88	---
GP-6	3.53	3.03	2.31	161
GP-7	4.27	4.00	2.09	184
GP-7 Dup	4.54	3.94	----	183
GP-8	2.31	1.77	2.02	93
GP-9	3.27	3.49	<.05	415
GP-10	3.27	3.51	1.66	204
Blank	<.5	<.5	<.05	---
Blank	<.5	<.5	<.05	---
WP033	59.0	21.2	0.27	---
WP033	58.3	20.5	.27	---
WP033 T.V.	59.2	22.0	0.27	---
Spike Rec.	100%	103%	100%	---
Spike Rec.	100%	101%	99%	---

MANTECH

Ref: 95-JH52/vg

King Salmon

August 25, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Find attached results for methane on samples received on July 31, 1995 and analyzed on August 7, 8, 9, 10, and 14, 1995 under Service Request #SF-1-135 Mod. 1. Samples were prepared and calculations were done as per RSKSOP-175. Analyses were performed as per RSKSOP-147.

Sample # ESMW-10B was wasted due to loose septa caps on both duplicates. If you have any questions, feel free to contact me.

Sincerely,

Jeff Hickerson

Jeff Hickerson

xc: R.L. Cosby
J.L. Seeley JS
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

SR# SF-1-135
MOD 1

FT01

ANALYSIS PERFORMED 8-7-95

SAMPLE	METHANE
LAB BLANK	BLQ
ESMW-1A	BLQ
ESMW-1B	BLQ
ESMW-2A	BLQ
ESMW-2B	BLQ
" FIELD DUP	BLQ
ESMW-3A	0.126
ESMW-4A	0.001
ESMW-5A	BLQ
ESMW-5B	0.001
ESMW-6B	0.074
" LAB DUP	0.071

ANALYSIS PERFORMED 8-8-95

SAMPLE	METHANE
LAB BLANK	BLQ
ESMW	BLQ
ESMW-15A	1.37
ESMW-15B	BLQ
MW-50	BLQ
" LAB DUP	BLQ
MW-93	0.123
MW-95	BLQ
MW-435	0.001
MW-460B	BLQ
MW-462C	0.045
" FIELD DUP	0.038
KAMW-653	BLQ

ANALYSIS PERFORMED 8-9-95

SAMPLE	METHANE
LAB BLANK	BLQ
ESMW-8A	8.04
ESMW-8B	0.413
ESMW-10A	1.69
ESMW-12A	4.24
" FIELD DUP	3.73
ESMW-14	0.015
ESMW-16	5.25
GP-5	BLQ
GP-6	0.025
GP-7	0.032
" LAB DUP	0.031
" FIELD DUP	0.067
GP-8	BLQ
GP-9	BLQ

ANALYSIS PERFORMED 8-10-95

SAMPLE	METHANE
LAB BLANK	BLQ
GP-10	BLQ
EMCON-1	BLQ
EMCON-2	BLQ
WP-1	6.61
" FIELD DUP	6.89
GP-1	BLQ
GP-2	BLQ
GP-3	BLQ
GP-4	BLQ
MW51	0.115
" LAB DUP	0.108

ANALYSIS PERFORMED 8-14-95

SAMPLE	METHANE
LAB BLANK	BLQ
MW-52	0.432
MW-88	BLQ
" FIELD DUP	BLQ
MW-89	BLQ
MW-90	ND
" FIELD DUP	BLQ
MW-92	BLQ
MW-94	0.390
MW-500	0.400
MW-501	0.001
MW-506	0.052
" LAB DUP	0.048
10 PPM CH4	10.00
100 PPM CH4	99.93
1000 PPM CH4	1071.46
1% CH4	1.00
10% CH4	10.00

LIMIT OF QUANTITATION

METHANE
0.001

SAMPLE UNITS ARE mg/L.
STANDARDS UNITS CORRESPOND
TO THE SAMPLE COLUMN.

BLQ DENOTES BELOW LIMIT OF QUANTITATION
ND DENOTES NONE DETECTED.
NA DENOTES NOT ANALYZED.

MANTECH ENVIRONMENTAL TECHNOLOGY

King Salmon

Ref: 95-TL42/vg

August 24, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV King Salmon

Dear Don:

Attached are TC, TOC, and TIC results for a set of 48 liquid samples received by MERSC July 31, 1995 under Service Request #SF-1-135. Determinations were begun August 21, 1995 and completed August 23, 1995 using RSKSOP-102.

A known AQC sample was analyzed with your samples for quality control. If you have any questions concerning these results please feel free to contact me.

Sincerely,

Teresa Leon

Teresa Leon

xc: R.L. Cosby
J.L. Seeley JJ
G.B. Smith

FT01

TC, TOC, TIC FOR DON KAMPBELL (SF-1-135)

SAMPLE	MG/L TC	MG/L TOC	MG/L TIC
EMCON-1	56.5	10.2	46.3
EMCON-2	21.2	2.2	19.0
WP-1	32.6	26.7	5.9
ESMW-1A	30.0	1.4	28.6
ESMW-1B	19.5	2.2	17.3
ESMW-2A	18.8	5.1	13.7
ESMW-2B	17.2	3.1	14.1
ESMW-3A	14.3	2.4	11.9
ESMW-4A	26.6	6.2	20.4
ESMW-5A	24.6	3.1	21.5
ESMW-5A DUP		3.1	
ESMW-5B	16.8	1.2	15.6
ESMW-6B	12.9	2.0	10.9
ESMW-8A	154.9	82.9	72.0
ESMW-8B	20.0	3.9	16.1
ESMW-8B DUP	20.1		
ESMW-12A	29.4	37.2	<0.1
ESMW-14	12.8	2.3	10.5
ESMW-15A	37.4	13.6	23.8
ESMW-15B	23.0	2.8	20.2
ESMW-16	34.0	10.4	23.6
MW-10A	32.5	8.5	24.0
MW-10A DUP		8.7	
MW-10B	14.7	1.3	13.4
MW-50	12.7	2.6	10.1
MW-51	35.4	14.2	21.2
MW-52	47.4	9.7	37.7
MW-52 DUP	47.2		
MW-88	16.1	1.8	14.3
MW-89	12.4	1.4	11.0
MW-90	9.3	1.8	7.5
MW-92	18.9	3.6	15.3
MW-93	10.3	1.6	8.7
MW-94	10.2	1.5	8.7
MW-94 DUP		1.4	
MW-95	16.3	5.0	11.3
MW-435	21.0	4.3	16.7
MW-460B	23.5	5.3	18.2
MW-462C	13.0	2.6	10.4
MW-462C DUP	13.0		
MW-500	40.8	13.0	27.8
MW-501	18.5	3.0	15.5
MW-506	10.7	1.1	9.6
KSMW-653	30.4	4.8	25.6
KSMW-653 DUP	30.3		
GP-1	28.1	1.8	26.3
GP-2	10.9	1.5	9.4
GP-2 DUP		1.5	
GP-3	17.3	1.7	15.6
GP-4	14.9	1.8	13.1
GP-5	14.1	3.2	10.9
GP-6	20.0	1.9	18.1
GP-6 DUP	19.9		
GP-7	27.2	3.4	23.8
GP-8	12.3	1.5	10.8
GP-9	77.1	12.3	64.8
GP-10	38.5	6.8	31.7
GP-10 DUP	38.6	6.8	31.8
WPO33-II		34.5	
		34.6	
		34.8	
		34.5	
		34.9	
		34.7	
		34.7	
		35.1	
		35.1	
		34.8	
		35.3	
		35.4	
		35.6	
		35.6	
		35.6	

TRUE VALUES: WPO33-II = 35.0 MG/L

MANTECH

Ref: 95-SH14/vg
95-TL40/vg

August 23, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV King Salmon

Dear Don:

Attached are TOC results for a set of 12 soils submitted August 14, 1995 under Service Request #SF-1-135. Sample analysis was begun August 18 and completed August 23 using RSKSOP-102 and RSKSOP-120. Blanks, duplicates, AQC samples and a Leco standard soil were analyzed along with your samples, as appropriate, for quality control.

If you have any questions concerning this data, please feel free to ask me.

Sincerely,

Sharon Hightower

Sharon Hightower

Teresa Leon

Teresa Leon

xc: R.L. Cosby
J.L. Seeley
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

Sample	Soil Filtrate % OC	Solids % OC	Total Soil %TOC	Mean %TOC
FTO1 SSO1 #1				
1-1	.111	1.13	1.24	1.24
1-2	.107	1.12	1.23	
FTO1 SSO1 #2				
1-1	.159	.728	.887	.943
1-2	.168	.830	.998	
FTO1 SSO2 #1				
1-1	.058	.392	.450	.470
1-2	.063	.426	.489	
FTO1 SSO2 #2				
1-1	.055	.489	.544	.554
1-2	.061	.502	.563	
UN Site SS-3 #1				
1-1	.318	3.07	3.39	3.58
1-2	.314	3.45	3.76	
UN Site SS-3 #2				
1-1	.721	11.21	11.93	12.2
1-2	.767	11.71	12.48	
UN Site SS-4 #1				
1-1	.476	7.52	8.00	7.91
1-2	.484	7.34	7.82	
UN Site SS-4 #2				
1-1	.410	6.94	7.35	7.26
1-2	.384	6.78	7.16	
UN Site SS-05 #1				
1-1	1.17	18.0	19.2	19.8
1-2	1.24	19.2	20.4	
UN Site SS-05 #2				
1-1	1.29	18.2	19.5	19.3
1-2	1.28	17.9	19.1	
UN Site SS-06 #1				
1-1	1.33	21.1	22.4	23.1
1-2	1.33	22.4	23.7	
UN Site SS-06 #2				
1-1	1.09	22.4	23.5	23.1
1-2	1.07	21.6	22.7	
Leco standard		1.04		
WP033-II std	35.1			

Leco standard T.V.=1.00±.04
WP033-II standard T.V.=35.0

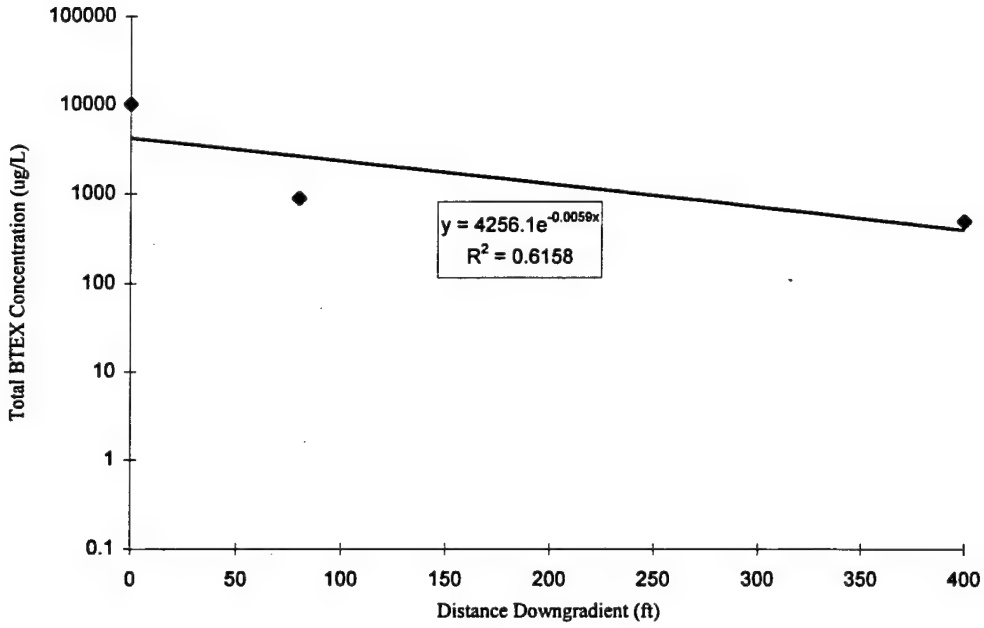
APPENDIX D

MODEL INPUT PARAMETERS AND RELATED CALCULATIONS

TABLE 5.2
FIRST-ORDER RATE CONSTANT CALCULATION
USING THE METHOD OF BUSCHECK AND ALCANTAR (1995)
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Point	Distance Downgradient	B, T, E, & X (µg/L) Oct-94
ESMW-1A	0	10136
MW95	80	894
435	400	490

PLOT OF TOTAL B, T, E, & X CONCENTRATION VERSUS DISTANCE



$$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$$

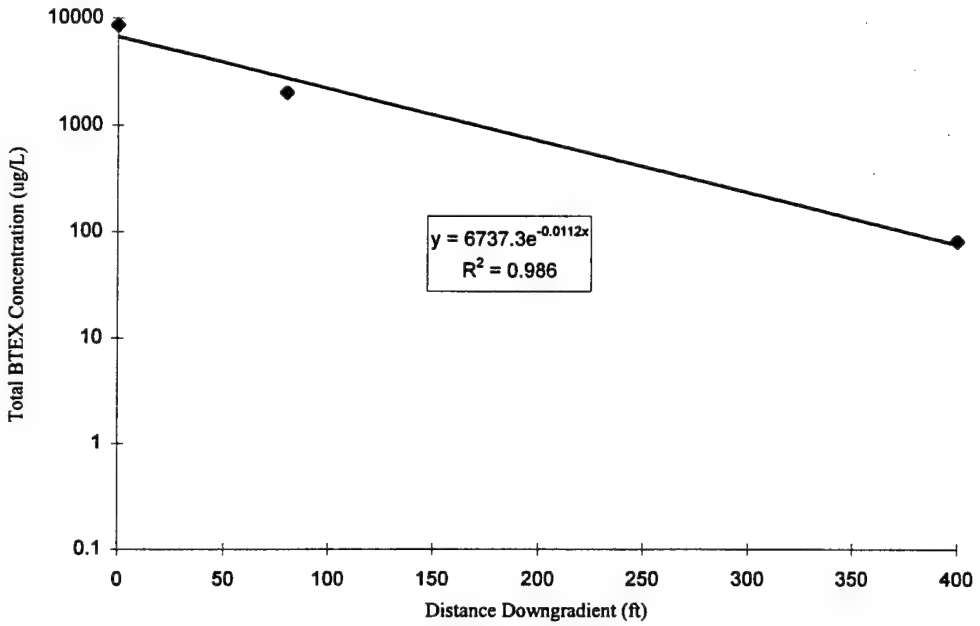
where $v_c = 0.45$
$\alpha_x = 35$
$k/v = 0.0059$

therefore $\lambda = 3.20E\text{-}03$

FIRST-ORDER RATE CONSTANT CALCULATION
USING THE METHOD OF BUSCHECK AND ALCANTAR (1995)
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Point	Distance Downgradient	B, T, E, & X (µg/L) Jul-95
ESMW-1A	0	8620
MW95	80	2020
435	400	81

PLOT OF TOTAL B, T, E, & X CONCENTRATION VERSUS DISTANCE



$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$

where $v_c = 0.45$

$\alpha_x = 35$

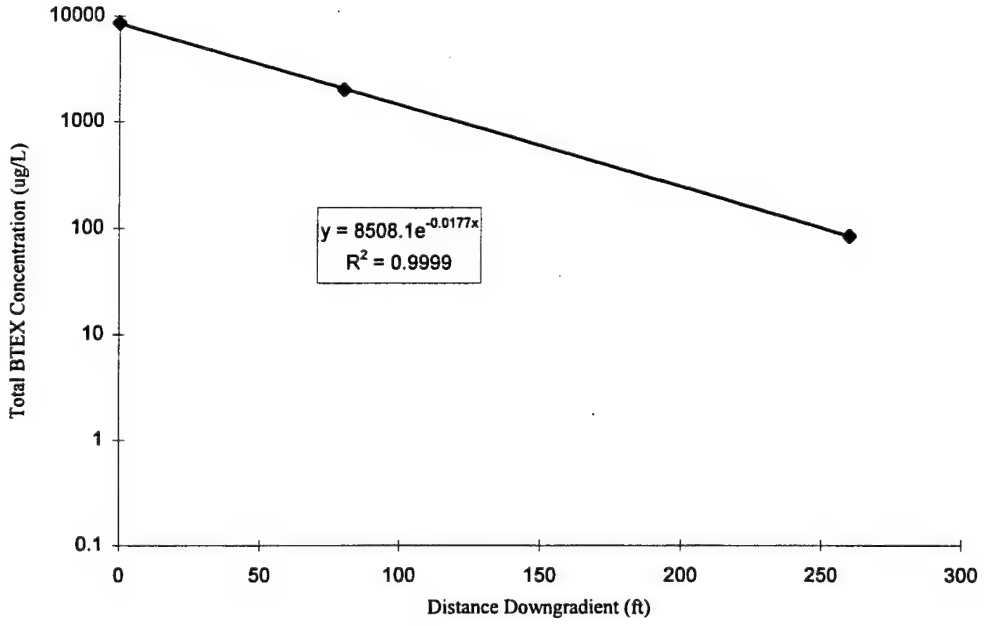
$k/v = 0.0112$

therefore $\lambda = 7.02E-03$

TABLE 5.2
FIRST-ORDER RATE CONSTANT CALCULATION
USING THE METHOD OF BUSCHECK AND ALCANTAR (1995)
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Point	Distance Downgradient	B, T, E, & X (µg/L) Jul-95
ESMW-1A	0	8620
MW95	80	2020
ESMW5A	260	85

PLOT OF TOTAL B, T, E, & X CONCENTRATION VERSUS DISTANCE



$$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$$

where $v_c = 0.45$
$\alpha_x = 35$
$k/v = 0.0177$

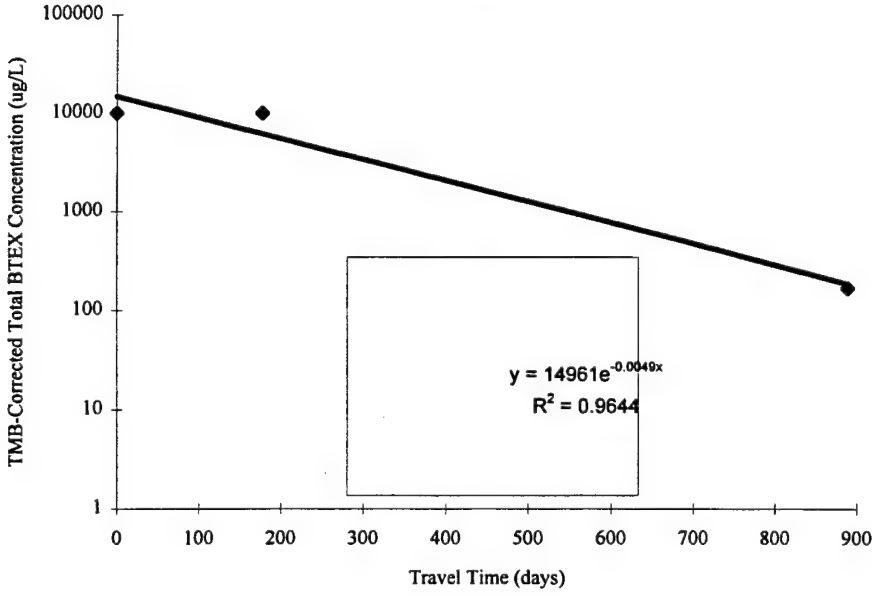
therefore $\lambda = 1.29E\text{-}02$

FIRST-ORDER RATE CONSTANT CALCULATION
USING TMB AS A CONSERVATIVE TRACER
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Point	Distance Downgradient (ft)	Travel Time Between Upgradient and Downgradient Point (days)	Measured Total BTEX Concentration (µg/L)	(1994) Total Trimethylbenzene Concentration (µg/L)	Trimethylbenzene-Corrected Total BTEX Concentration (µg/L)
ESMW-1A	0	0	10136	555	10136
MW95	80	178	894	49.0	10126
435	400	889	490	142.0	169

v_c = 0.45 ft/day

PLOT OF TMB-CORRECTED TOTAL BTEX CONCENTRATION VERSUS TIME

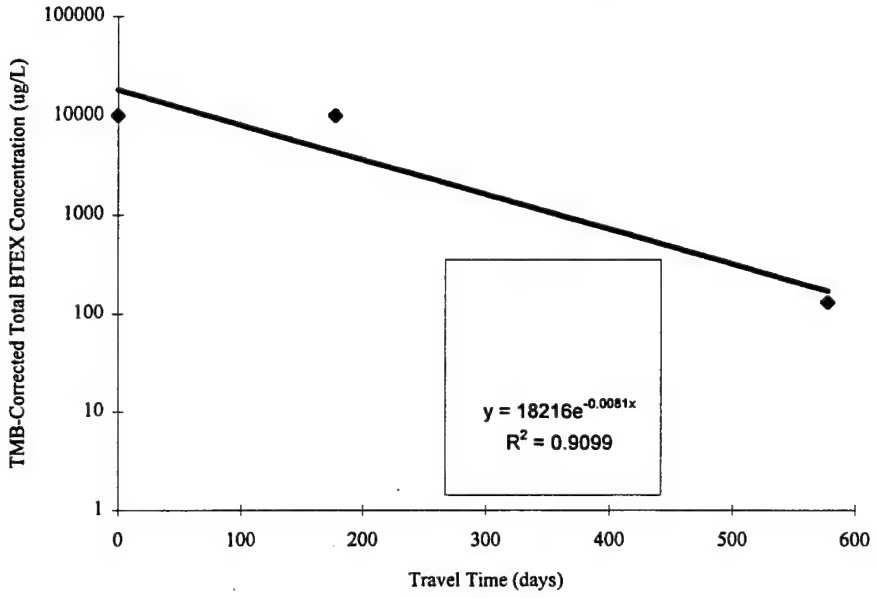


FIRST-ORDER RATE CONSTANT CALCULATION
USING TMB AS A CONSERVATIVE TRACER
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Point	Distance Downgradient (ft)	Travel Time Between Upgradient and Downgradient Point (days)	Measured Total BTEX Concentration (µg/L)	(1994) Total Trimethylbenzene Concentration (µg/L)	Trimethylbenzene-Corrected Total BTEX Concentration (µg/L)
ESMW-1A	0	0	10136	555	10136
MW95	80	178	894	49.0	10126
ESMW5A	260	578	714	263.4	133

v_c = 0.45 ft/day

PLOT OF TMB-CORRECTED TOTAL BTEX CONCENTRATION VERSUS TIME

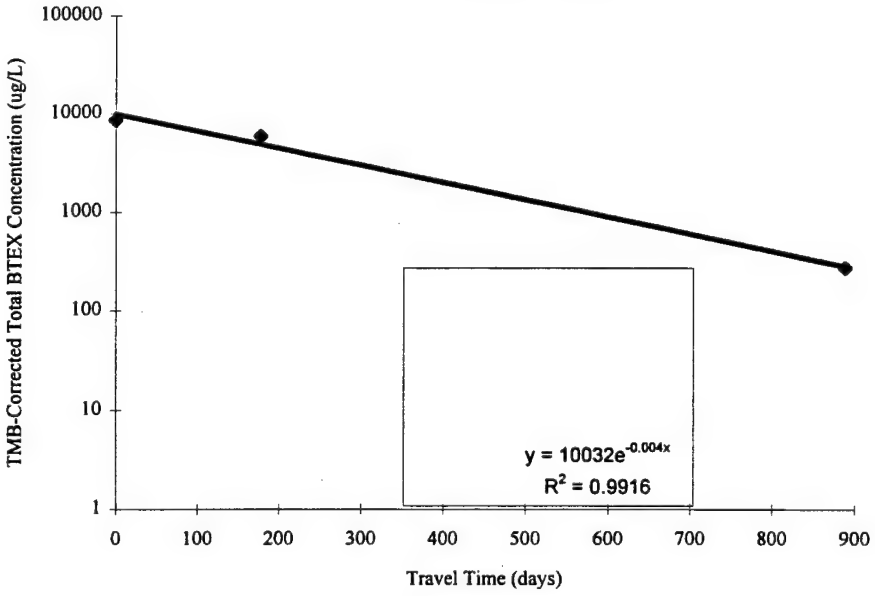


FIRST-ORDER RATE CONSTANT CALCULATION
USING TMB AS A CONSERVATIVE TRACER
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Point	Distance Downgradient (ft)	Travel Time Between Upgradient and Downgradient Point (days)	Measured Total BTEX Concentration (µg/L)	(1995) Total Trimethylbenzene Concentration (µg/L)	Trimethylbenzene-Corrected Total BTEX Concentration (µg/L)
ESMW-1A	0	0	8620	448	8620
MW95	80	178	2020	152.1	5951
435	400	889	81	44.8	275

v_c = 0.45 ft/day

PLOT OF TMB-CORRECTED TOTAL BTEX CONCENTRATION VERSUS TIME

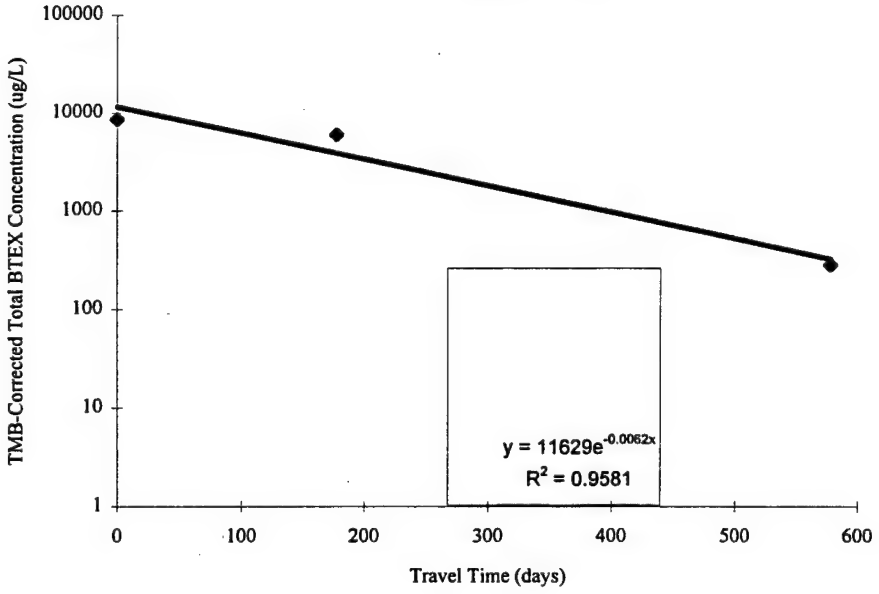


FIRST-ORDER RATE CONSTANT CALCULATION
USING TMB AS A CONSERVATIVE TRACER
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Point	Distance Downgradient (ft)	Travel Time Between Upgradient and Downgradient Point (days)	Measured Total BTEX Concentration (µg/L)	(1995) Total Trimethylbenzene Concentration (µg/L)	Trimethylbenzene-Corrected Total BTEX Concentration (µg/L)
ESMW-1A	0	0	8620	448	8620
MW95	80	178	2020	152.1	5951
ESMW5A	260	578	85	45.7	283

v_c = 0.45 ft/day

PLOT OF TMB-CORRECTED TOTAL BTEX CONCENTRATION VERSUS TIME

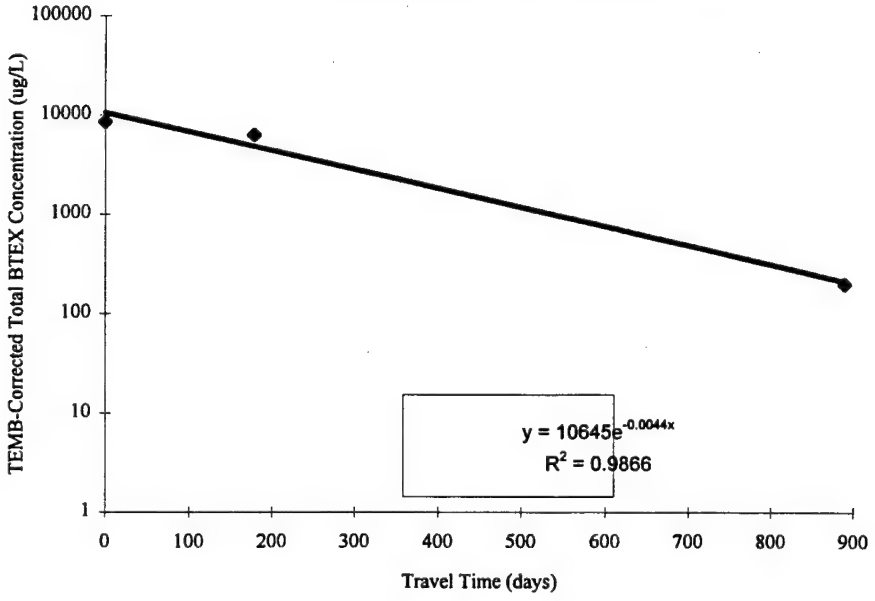


FIRST-ORDER RATE CONSTANT CALCULATION
USING TETRAMETHYLBENZENE AS A CONSERVATIVE TRACER
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Point	Distance Downgradient (ft)	Travel Time Between Upgradient and Downgradient Point (days)	Measured Total BTEX Concentration (µg/L)	(1995) Total Tetramethylbenzene Concentration (µg/L)	Tetramethylbenzene Corrected Total BTEX Concentration (µg/L)
ESMW-1A	0	0	8620	47.3	8620
MW95	80	178	2020.0	15.1	6328
435	400	889	81	6.1	201

v_c = 0.45 ft/day (average for all BTEX compounds)

PLOT OF TEMB-CORRECTED TOTAL BTEX CONCENTRATION VERSUS TIME



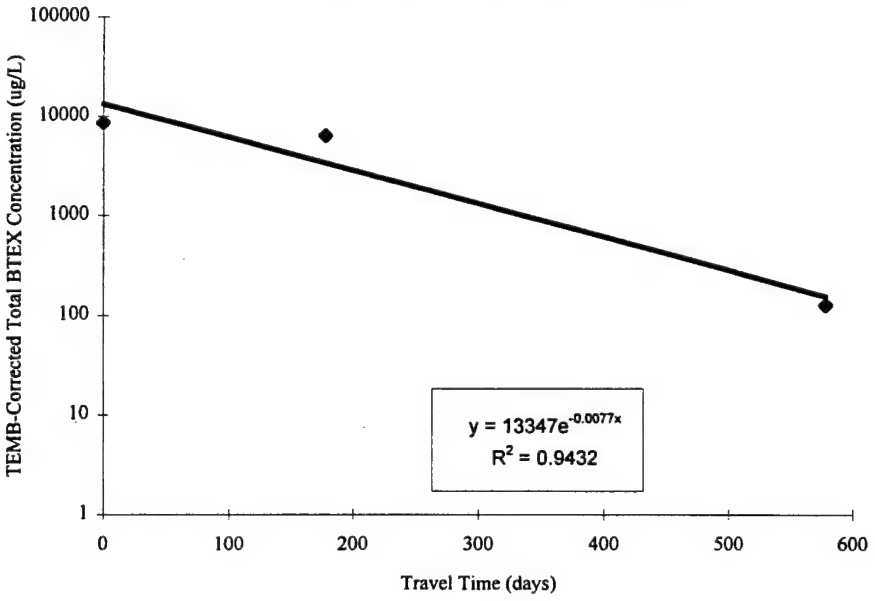
C:\KING\TEMB1.XLS

FIRST-ORDER RATE CONSTANT CALCULATION
USING TETRAMETHYLBENZENE AS A CONSERVATIVE TRACER
FIRE TRAINING AREA FT01
INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

Point	Distance Downgradient (ft)	Travel Time Between Upgradient and Downgradient Point (days)	Measured Total BTEX Concentration (µg/L)	(1995) Total Tetramethylbenzene Concentration (µg/L)	Tetramethylbenzene Corrected Total BTEX Concentration (µg/L)
ESMW-1A	0	0	8620	47.3	8620
MW95	80	178	2020.0	15.0	6370
ESMW-5A	260	578	85	10.0	128

v_c = 0.45 ft/day (average for all BTEX compounds)

PLOT OF TEMB-CORRECTED TOTAL BTEX CONCENTRATION VERSUS TIME



RMS Error Calculations for Calibrated Flow Model
King Salmon Airport, Alaska

Well	Cell Location x,y	Measured Head Hm	Simulated Head Hs	Hm-Hs	(Hm-Hs)2
MW-93	(11,6)	63.81	63.71	0.1	0.0100
MW-94	(15,7)	63.39	63.36	0.03	0.0009
MW-92	(10,10) (11,10)	62.71	62.61	0.1	0.0100
ESMW-1A	(14,9) (14,10) (15,9) (15,10)	62.69	62.63	0.06	0.0036
MW-95	(14,11)	62.32	62.28	0.04	0.0016
ESMW-2A	(16,12) (17,12)	61.69	61.93	-0.24	0.0576
ESMW-4A	(13,13)	61.73	61.86	-0.13	0.0169
ESMW-5A	(14,14) (15,14)	61.33	61.59	-0.26	0.0676
ESMW-7A	(20,17) (20,18)	61.39	61.31	0.08	0.0064
653	(14,20) (15,20)	61.4	61.25	0.15	0.0225

Sum of Squares of Differences	0.1971
Average of Squares of Differences	0.01971
RMS (square root of average of squares of diff	0.140392
RMS as a percentage of the head drop over the model domain (about 2.4 feet)	5.849679

Simulated Head vs. Measured Head, Calibrated Groundwater Flow Model, MacDill AFB Site 56

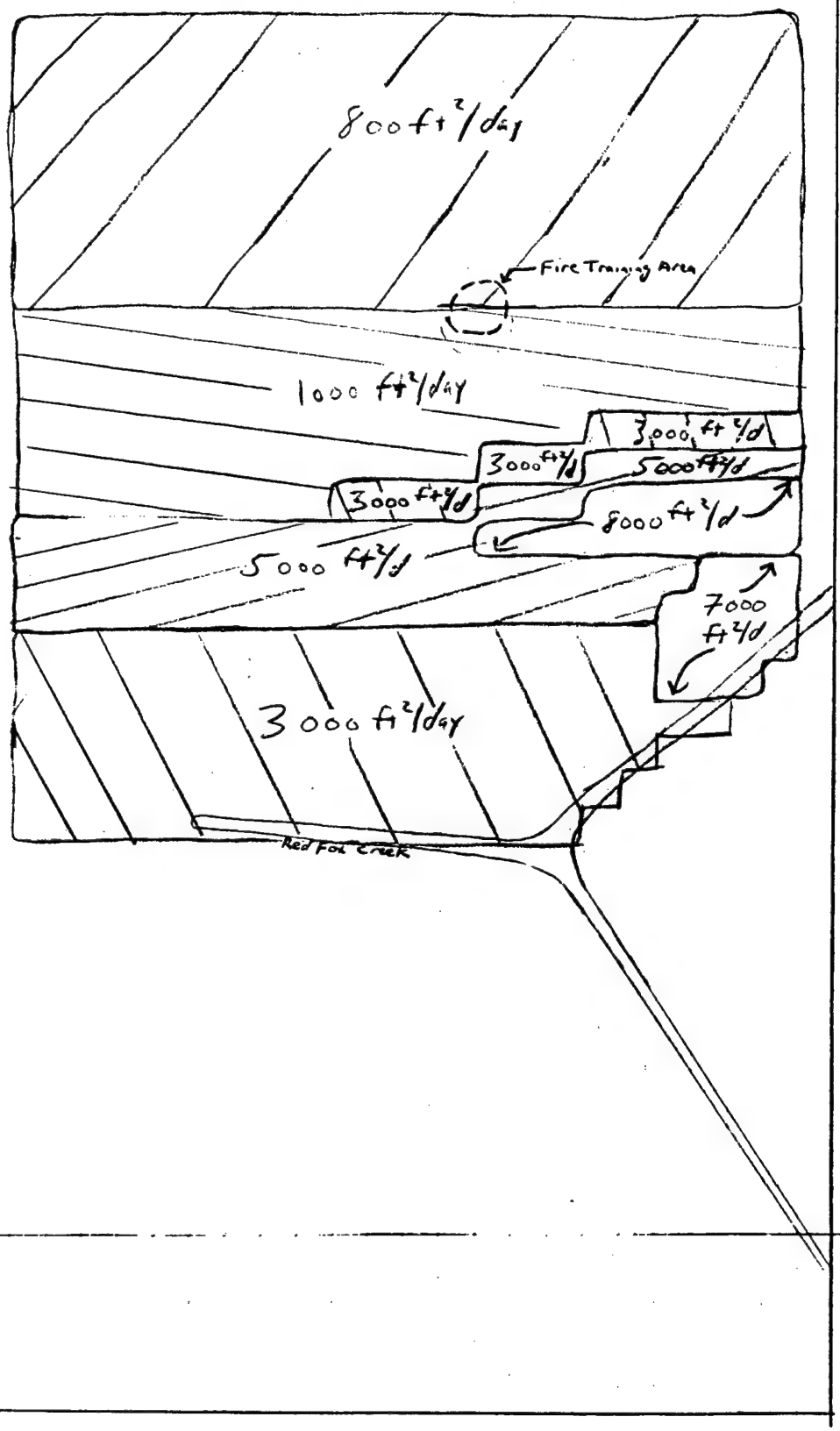
RMS Error Calculations for Calibrated Flow Model					
King Salmon Airport, Alaska					
Well	Cell Location	Measured Head	Simulated Head	Hm-Hs	(Hm-Hs)2
	x,y	Hm	Hs		
MW-93	(11,6)	63.81	63.71	0.1	0.0100
MW-94	(15,7)	63.39	63.36	0.03	0.0009
MW-92	(10,10) (11,10)	62.71	62.61	0.1	0.0100
ESMW-1A	(14,9) (14,10) (15,9) (15,10)	62.69	62.63	0.06	0.0036
MW-95	(14,11)	62.32	62.28	0.04	0.0016
ESMW-3A	(19,10)	62.05	62.39	-0.34	0.1156
462C	(20,11)	61.64	62.09	-0.45	0.2025
ESMW-2A	(16,12) (17,12)	61.69	61.93	-0.24	0.0576
ESMW-4A	(13,13)	61.73	61.86	-0.13	0.0169
ESMW-5A	(14,14) (15,14)	61.33	61.59	-0.26	0.0676
ESMW-7A	(20,17) (20,18)	61.39	61.31	0.08	0.0064
653	(14,20) (15,20)	61.4	61.25	0.15	0.0225
		Sum of Squares of Differences			0.5152
		Average of Squares of Differences			0.042933
		RMS (square root of average of squares of diff			0.207204
		RMS as a percentage of the head drop			8.633483
		over the model domain (about 2.4 feet)			

ES ENGINEERING-SCIENCE, INC.

Client AFCEE / Kelly Salmon Airport
Subject Transmissivity Array
Fire Training Area FT 01

Job No. 722450.71030
By JRH
Checked

Sheet 1 of 1
Date 4-3-96
Rev.



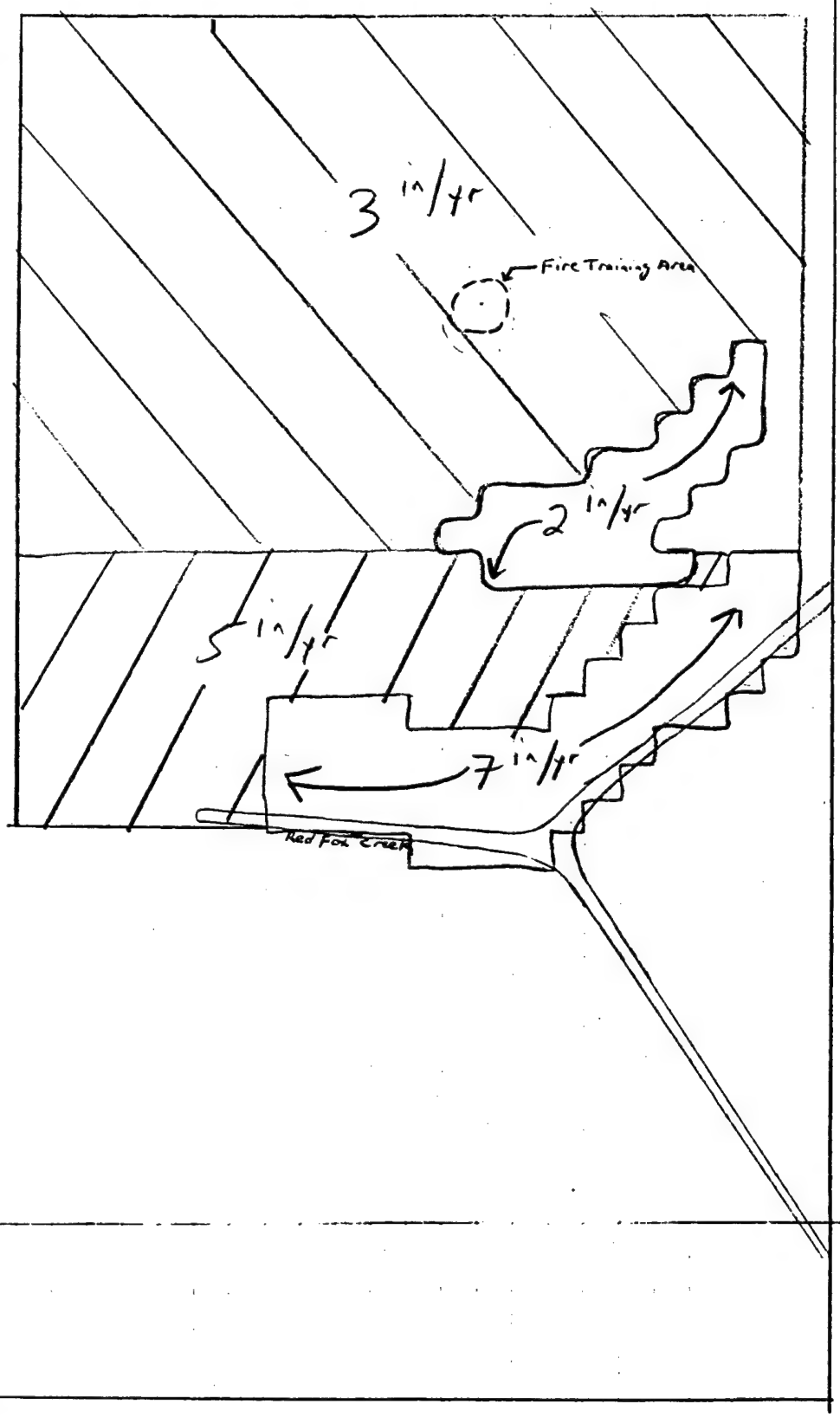
Note:
Transmissivity values input in the model in ft²/second

ENGINEERING-SCIENCE, INC.

Client AFCEE / Kelly Salmon Airport
Subject Recharge Array
Fire Training Zone FT01

Job No. 722450.71030
By JRH
Checked

Sheet 1 of 1
Date 4-3-96
Rev.



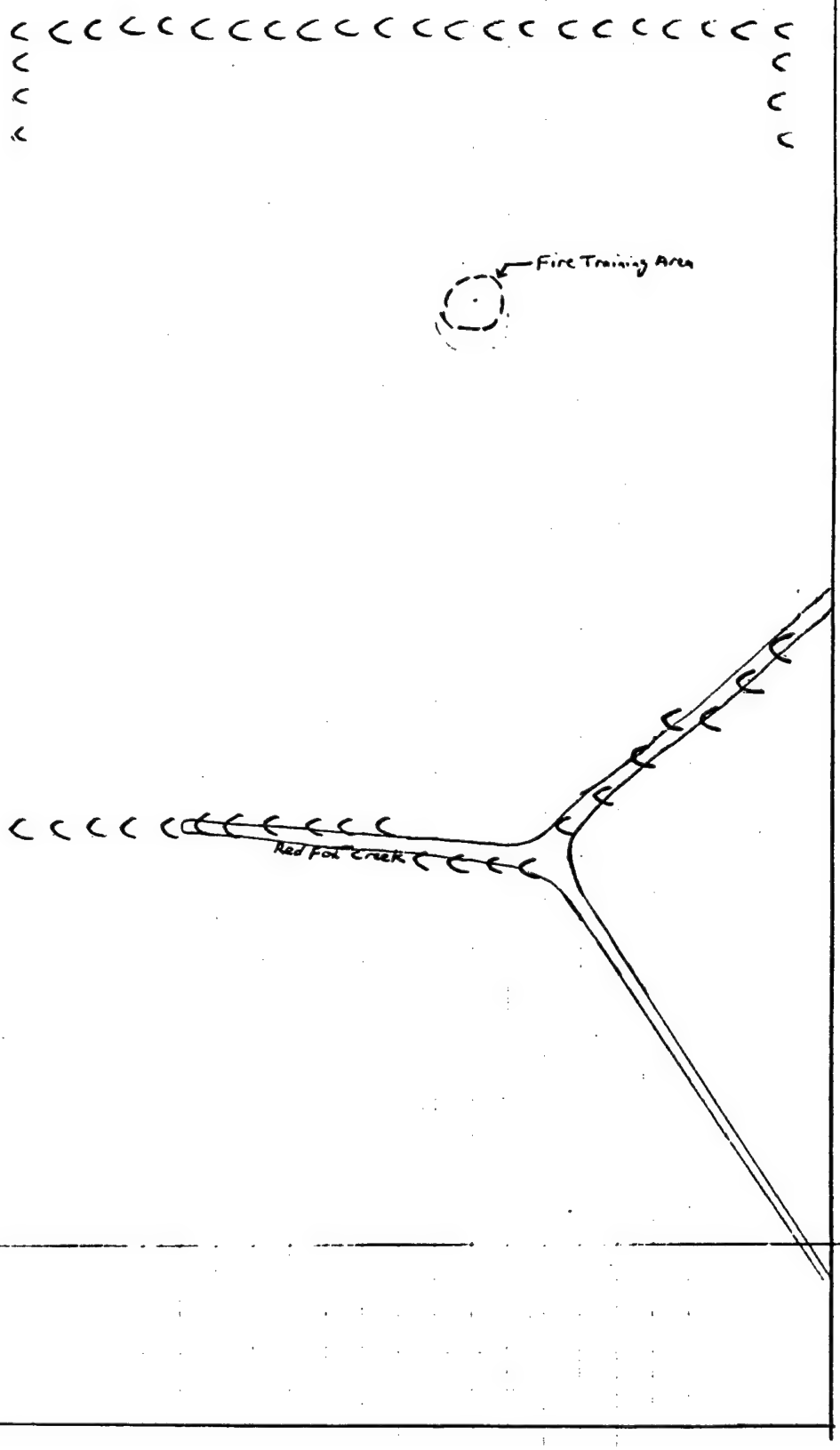
Note:
Recharge Values Entered into model in ft/sec

ES ENGINEERING-SCIENCE, INC.

Client: AFCEE / Kelly Salmon Airport
Subject: Constant Head Cells (C) Fire Training Area FTO1

Job No. 722450.71030
By JRH
Checked

Sheet 1 of 1
Date 4-3-96
Rev.



APPENDIX E

MODEL INPUT AND OUTPUT FILES

APPENDIX F

REMEDIAL ALTERNATIVE DESIGN AND COST CALCULATIONS

Present Worth Analysis

Annual Adjustment Factor = 7%

Alternative 1: Intrinsic Remediation with Institutional Controls and Long-Term Groundwater Monitoring	years	Present Worth ($)	Cost ($) at Year Indicated: Year: 1	5	10	13	15	20	30	35
Maintain Institutional Controls	35	$64,738	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Long-term Monitoring										
Install New Wells	1	$19,115	$20,453	$0	$0	$0	$0	$0	$0	$0
Groundwater Sampling at Site FT01	12	$35,949	$4,526	$4,526	$4,526	$0	$0	$0	$0	$0
Ground/Surface Water Sampling at RAPCON sit	35	$105,632	$8,146	$8,146	$8,146	$10,692	$10,692	$10,692	$5,346	$5,346
Reporting/Project Mgmt	35	$93,636	$7,455	$7,455	$7,455	$7,455	$7,455	$7,455	$6,228	$6,228
Subtotal Present Worth ($)		$319,069								

Total Present Worth Cost ($): $319,069

Present Worth Analysis Annual Adjustment Factor = 7%

Alternative 2: Intrinsic Remediation, Source Excavation at RAPCON site, and Institutional Controls and Long-Term Monitoring		Present Worth	Cost ($) at Year Indicated							
	years	($)	Year: 1	5	10	13	15	20	30	35
Maintain Institutional Controls	20	$52,970	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$0	$0
Long-term Monitoring										
Install New Wells	1	$19,115	$20,453	$0	$0	$0	$0	$0	$0	$0
Groundwater Sampling at Site FT01	12	$35,949	$4,526	$4,526	$4,526	$0	$0	$0	$0	$0
Ground/Surface Water Sampling at RAPCON sit	20	$93,049	$8,146	$8,146	$8,146	$10,692	$10,692	$10,692	$0	$0
Reporting/Project Mgmt	20	$78,978	$7,455	$7,455	$7,455	$7,455	$7,455	$7,455	$0	$0
Subtotal Present Worth ($)		$280,061								
Excavation										
Preliminary Site Investigation	1	$23,964	$25,642							
Excavation	1	$40,321	$43,144	$0	$0	$0	$0	$0	$0	$0
Bioventing Pile Maintenance	1	$13,162	$3,000	$3,000	$0	$0	$0	$0	$0	$0
Reporting Costs	1	$8,774	$2,000	$2,000	$0	$0	$0	$0	$0	$0
		$86,222								

Total Present Worth Cost ($): $366,283

Present Worth Analysis Annual Adjustment Factor = 7%

Alternative 3: Intrinsic Remediation, Source Excavation at RAPCON site, Biosparging, Institutional Controls and Long-Term Monitoring		Present Worth	Cost ($) at Year Indicated							
	years	($)	Year: 1	5	10	13	15	20	30	35
Maintain Institutional Controls	20	$52,970	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$0	$0
Long-term Monitoring										
Install New Wells	1	$19,115	$20,453	$0	$0	$0	$0	$0	$0	$0
Groundwater Sampling at Site FT01	12	$35,949	$4,526	$4,526	$4,526	$0	$0	$0	$0	$0
Ground/Surface Water Sampling at RAPCON sit	20	$93,049	$8,146	$8,146	$8,146	$10,692	$10,692	$10,692	$0	$0
Reporting/Project Mgmt	20	$78,978	$7,455	$7,455	$7,455	$7,455	$7,455	$7,455	$0	$0
Subtotal Present Worth ($)		$280,061								
Excavation										
Preliminary Site Investigation	1	$23,964	$25,642							
Excavation	1	$40,321	$43,144	$0	$0	$0	$0	$0	$0	$0
Bioventing Pile Maintenance	1	$13,162	$3,000	$3,000	$0	$0	$0	$0	$0	$0
Reporting Costs	1	$8,774	$2,000	$2,000	$0	$0	$0	$0	$0	$0
		$86,222								
Biosparging										
Biosparging System Installation	1	$135,227	$68,275	$39,508	$39,508	$0	$39,508	$0	$0	$0
System Maintenance	20	$115,263	$10,880	$10,880	$10,880	$10,880	$10,880	$10,880	$0	$0
Reporting Costs	20	$46,042	$4,346	$4,346	$4,346	$4,346	$4,346	$4,346	$0	$0
		$296,531								

Total Present Worth Cost ($): $662,814

Alternatives 1 to 3: Long-Term Monitoring and Institutional Controls

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1 (hrs)	Install New LTM/POC Wells ($)	Task 2 (hrs)	Sampling ($)	Task 3 (hrs)	Reporting & PM ($)
Word Processor 88/(15)	$30	0	$0	0	$0	30	$900
CADD Operator 58/(25)	$47	4	$188	0	$0	10	$470
Technician 42/(50)	$40	5	$200	24	$960	16	$640
Staff Level 16/(65)	$57	100	$5,700	16	$912	40	$2,280
Project Level 12/(70)	$65	8	$520	4	$260	30	$1,950
Senior Level 10/(80)	$85	1	$85	0	$0	3	$255
Principal 02/(85)	$97	0	$0	0	$0	0	$0
Total Labor (hrs | $)		118	$6,693	44	$2,132	129	$6,495
ODCs							
Phone			$30		$0		$50
Photocopy			$20		$0		$150
Mail			$100		$400		$60
Computer			$150		$0		$200
CAD			$0		$0		$300
WP			$0		$0		$200
Travel			$1,000		$2,000		$0
Per Diem			$360		$360		$0
Eqpt. & Supplies			$400		$200		$0
Total ODCs			$2,060		$2,960		$960
Outside Services							
LTM/POC Well Installation Costs [a/]			$11,100		$0		$0
Laboratory Fees [b/]							$0
Site FT01		Soils	$600	6 LTM, 4 qa/qc	$1,980		
RAPCON Site				6 LTM, 4 sur., and 4 qa/qc,	$5,600		
Other: Maintain Institutional Controls			$0				$5,000
Total Outside Services			$11,700		$7,580		$5,000

Proposal Estimate	Task 1	Task 2	Task 3
Labor	$6,693	$2,132	$6,495
ODC's	$2,060	$2,960	$960
Outside Services	$11,700	$7,580	$5,000
Total by Task	$20,453	$12,672	$12,455

Total Labor	$15,320
Total ODCs	$5,980
Total Outside Services	$24,280
Total Project	$45,580

Task 1: Install New LTM/POC Wells

Task 2: Sampling per Event

Task 3: Reporting and PM per Sampling Event

[a/] 8 Wells, 160ft @ $50/ft, $2000mob, $700 soil handling

[b/] (BTEX @ $120ea (SW8020), Halogenated VOCs @ $200 ea (SW8060), electron acceptors at LTM wells @ 150 ea)

Alternative 2: Excavation

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1 (hrs)	Plan and Conduct Excav. ($)	Task 2 (hrs)	Monitoring (per yr)($)	Task 3 (hrs)	Final Letter Report ($)
Word Processor 88/(15)	$30	8	$240	0	$0	8	$240
CADD Operator 58/(25)	$47	8	$376	0	$0	8	$376
Technician 42/(50)	$40	80	$3,200	0	$0	0	$0
Staff Level 16/(65)	$57	100	$5,700	0	$0	50	$2,850
Project Level 12/(70)	$65	16	$1,040	0	$0	16	$1,040
Senior Level 10/(80)	$85	4	$340	0	$0	0	$0
Principal 02/(85)	$97	1	$97	0	$0	0	$0
Total Labor (hrs|$)		217	$10,993	0	$0	82	$4,506
ODCs							
Phone					$0		$0
Photocopy			$500		$0		$0
Mail			$200		$0		$0
Computer			$500		$0		$0
CAD			$500		$0		$0
WP			$200		$0		$0
Travel			$2,000		$0		$0
Per Diem			$4,578		$0		$0
Eqpt. & Supplies			$2,000		$0		$0
Total ODCs			$10,478		$0		$0
Outside Services							
Excavation			$18,240		$0		$0
Backfill			$13,110		$0		$0
Equipment Costs			$0		$0		$0
Product Hauling/Disposal (Soil)			$9,120		$0		$0
Contingency			$2,274		$0		$0
Electrical Costs			$400		$0		$0
Laboratory Fees /O&M of Biopile			$3,000		$0		$0
Reporting by Base Personnel			$0		$0		$2,000
Other			$0		$0		$0
Total Outside Services			$46,144		$0		$2,000

Estimate	Task 1	Task 2	Task 3
Labor	$10,993	$0	$4,506
ODC's	$10,478	$0	$0
Outside Services	$46,144	$0	$2,000
Total by Task	$67,615	$0	$6,506

Total Labor	$15,499
Total ODCs	$10,478
Total Outside Services	$48,144
Total Project	$74,121

Task 1: Plan and Conduct Site Excavation
Task 2: Monthly Site Time and Travel Costs (per year)
Task 3: Letter Report Preparation

Alternative 3: Biosparging

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1 (hrs)	Design & Install Biospar. System ($)	Task 2 (hrs)	System Monitoring/ Maintenance (2x per yr)($)	Task 3 (hrs)	End of Year Report ($)
Word Processor 88/(15)	$30	40	$1,200	0	$0	8	$240
CADD Operator 58/(25)	$47	100	$4,700	0	$0	8	$376
Technician 42/(50)	$40	200	$8,000	80	$3,200	8	$320
Staff Level 16/(65)	$57	200	$11,400	20	$1,140	40	$2,280
Project Level 12/(70)	$65	100	$6,500	10	$650	8	$520
Senior Level 10/(80)	$85	8	$680	0	$0	2	$170
Principal 02/(85)	$97	1	$97	0	$0	0	$0
Total Labor (hrs|$)		649	$32,577	110	$4,990	74	$3,906
ODCs							
Phone					$120		$20
Photocopy			$500		$60		$100
Mail			$200		$240		$40
Computer			$500		$0		$200
CAD			$500		$0		$40
WP			$200		$0		$40
Travel			$2,000		$2,000		$0
Per Diem			$4,578		$1,070		$0
Eqpt. & Supplies			$2,000		$400		$0
Total ODCs			$10,478		$3,890		$440
Outside Services							
Well Installation			$14,640		$0		$0
System Installation			$5,580		$0		$0
Equipment Costs			$2,500		$0		$0
Product Hauling/Disposal (Soil)			$1,000		$0		$0
Electrical Costs			$2,000		$0		$0
Laboratory Fees			$1,500		$2,000		$0
Other			$0		$0		$0
Total Outside Services			$25,220		$2,000		$0

Estimate	Task 1	Task 2	Task 3
Labor	$32,577	$4,990	$3,906
ODC's	$10,478	$3,890	$440
Outside Services	$25,220	$2,000	$0
Total by Task	$68,275	$10,880	$4,346

Total Labor	$41,473
Total ODCs	$14,808
Total Outside Services	$27,220
Total Project	$83,501

Task 1: Biosparging System Design and Construction
Task 2: Monthly Site Time and Travel Costs (per year)
Task 3: Report Preparation

Preliminary Soil-Gas Study and Soil Sampling for RAPCON site.

Standard Rate Schedule

Billing Category / Cost Code/(Billing Category)	Billing Rate	Task 1 (hrs)	Plan Site Invest. ($)	Task 2 (hrs)	System Monitoring/ Maintenance (2x per yr)($)	Task 3 (hrs)	End of Year Report ($)
Word Processor 88/(15)	$30	12	$360	0	$0	8	$240
CADD Operator 58/(25)	$47	12	$564	0	$0	8	$376
Technician 42/(50)	$40	50	$2,000	0	$0	8	$320
Staff Level 16/(65)	$57	100	$5,700	0	$0	40	$2,280
Project Level 12/(70)	$65	16	$1,040	0	$0	4	$260
Senior Level 10/(80)	$85	4	$340	0	$0	1	$85
Principal 02/(85)	$97	1	$97	0	$0	0	$0
Total Labor (hrs | $)		195	$10,101	0	$0	69	$3,561
ODCs							
Phone					$0		$20
Photocopy			$250		$0		$100
Mail			$100		$0		$40
Computer			$200		$0		$200
CAD			$200		$0		$40
WP			$100		$0		$40
Travel			$2,000		$0		$0
Per Diem			$1,620		$0		$0
Eqpt. & Supplies			$500		$0		$0
Total ODCs			$4,970		$0		$440
Outside Services							
Soil Borehole Logging			$3,250		$0		$0
System Installation			$0		$0		$0
Equipment Costs			$420		$0		$0
Product Hauling/Disposal (Soil)			$400		$0		$0
Electrical Costs			$0		$0		$0
Laboratory Fees			$2,500		$0		$0
Other			$0		$0		$0
Total Outside Services			$6,570		$0		$0

Estimate	Task 1	Task 2	Task 3
Labor	$10,101	$0	$3,561
ODC's	$4,970	$0	$440
Outside Services	$6,570	$0	$0
Total by Task	$21,641	$0	$4,001

Total Labor	$13,662
Total ODCs	$5,410
Total Outside Services	$6,570
Total Project	$25,642

Task 1: Planning and Performance of RAPCON Site Characterization
Task 2: Monthly Site Time and Travel Costs (per year)
Task 3: Report Preparation

King Salmon Airport (Site FT01) Backup Calculations

Alternatives 1 : Long-term Monitoring

Misc calculations

Number of LTM wells:		
Number of wells:	8	
Depth each:	20	ft

Cost calculations

Description	Unit	Qty.	Unit Price	Subtotal	Total	Source (If applicable)
Well Installation					$ 11,100	
Mobilization	ea	1	$ 2,000	$ 2,000		
Well Installation	ln ft	160	$ 50	$ 8,000		
Soil Disposal	drum	11	$ 100	$ 1,100		

Alternative 2: Excavation

Misc calculations

Excavation Volume/Area		
Radius	35	ft
Depth:	8	ft
Volume:	30,788	cf
	1,140	cy
Surface Area:	3,848	sf
	428	sy

Cost calculations

Description	Unit	Qty.	Unit Price	Subtotal	Total	Source (If applicable)
					$ 47,744	
Soil Excavation	cy	1,140	$ 16	$ 18,240		
Backfill Purchase /Delivery	cy	1,311	$ 10	$ 13,110		*Quantity increased by 15% to account for soil expansion (Involves the collection and trucking of soil to the landfarm)
Soil Hauling /Disposal	cy	1,140	$ 8	$ 9,120		
Sampling	cell	1	$ 5,000	$ 5,000		*Price is required for yearly sampling, maintenance, and reporting for the bioventing treatment cell receiving soils.
Contingency	%	5%	$ 45,470	$ 2,274		

Alternative 3: Biosparging

Misc calculations

Number of sparging wells:		
Number of wells:	7	
Number of MPs:	4	
Depth each:	18	ft
Trench Volume/Area		
Width:	12	in
Depth:	1	ft
Length:	200	ft
Volume:	200	cf
	7	cy
Surface Area:	200	sf
	22	sy

Cost calculations

Description	Unit	Qty.	Unit Price	Subtotal	Total	Source (If applicable)
Point Installation					$ 14,640	
Mobilization	ea	1	$ 2,000	$ 2,000		
Well Installation	ln ft	126	$ 60	$ 7,560		
MP Installation	ln ft	72	$ 40	$ 2,880		
Soil Disposal	drum	11	$ 200	$ 2,200		
Equipment Costs					$ 2,500	
Blower	ea	1	$ 2,000	$ 2,000		Recovery Equipment Supply
Blower House	ea	1	$ 500	$ 500		
System Installation					$ 5,580	
Mob/Demob	ea	1	$ 1,000	$ 1,000		
Trenching	cy	7	$ 5.05	$ 35		Means 022 254 0050
Pipe laying	ln ft	240	$ 2.50	$ 600		Means 151 701 0550/026 686 2800
Backfill	cy	7	$ 17.20	$ 120		Means 022 204 0600
Compaction	cy	7	$ 5.10	$ 36		Means 022 204 0600
Pavement Base	sy	-	$ 5.25	$ -		Means 022 308 0100
Reseeding	sy	-	$ 1.91	$ -		Means 029 304 0310
Piping	lf	280	$ 1.00	$ 280		Means 151 551 1880
Mechanical	man hr	32	$ 38.83	$ 1,243		Means Q-1 crew
Electrical	ls	1	$ 2,000	$ 2,000		
Slab	cy	-	$ 97.00	$ -		Means 033 130 4700
Contingency	%	5%	$ 5,314	$ 266		
Product Hauling /Disposal (Soil)	load	1	$ 1,000	$ 1,000	$ 1,000	

King Salmon Airport (Site FT01) Backup Calculations

Preliminary Soil-Gas Study and Soil Sampling

Misc calculations

Number of Soil Boreholes:		
Boreholes	5	
Depth each:	10	ft

Cost calculations

Description	Unit	Qty.	Unit Price	Subtotal	Total	Source (If applicable)
Soil Boreholes					$ 4,070	
Mobilization	ea	1	$ 2,000	$ 2,000		
Borehole Logging	ln ft	50	$ 25	$ 1,250		($50 unit price reduced because well materials not required)
Soil Disposal	drum	4	$ 100	$ 400		
Equipment Costs						
PID	week	1	$ 420	$ 420		

APPENDIX G

RESPONSES TO COMMENTS

PARSONS

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10 September 1999

Mr. Jerry Hansen
Technical Program Manager
AFCEE/ERT
3207 North Road, Bldg. 532
Brooks AFB, TX 78235-5363

Subject: Responses to AFCEE Comments on the Draft Intrinsic Remediation Treatability Study for Site FT01, King Salmon Airport, Alaska (Contract F41624-92-D-8036-0006)

Dear Mr. Hansen:

This letter provides responses to comments received on the Draft Intrinsic Remediation Treatability Study (TS) for Site FT01, King Salmon Airport, Alaska. This draft report was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) and Elmendorf Air Force Base (AFB). The intent of the report was to summarize the results of a natural attenuation TS for the remediation of groundwater contaminated with fuel hydrocarbons at the former Fire Training Area No. 1 (FT01), King Salmon Airport, Alaska. The draft report was submitted to AFCEE in May 1996. Comments on the draft report were received from AFCEE as reviewed by Mr. Jon Atkinson of HQ AFCEE/ERT, dated December 16, 1996. Responses to these comments were prepared by Parsons ES and are presented herein.

GENERAL COMMENTS

Comment 1) Page ES-2, para 2, Sent 3: Based on statements on pages 3-1 (Sec 3.1.1) and 3-5 (Sec 3.4.1), Red Fox Creek is not a continuously flowing (perennial) stream as stated; rather, it is an intermittent stream. Consequently, this sentence needs to be revised accordingly.

Parsons ES Response: *Agreed. The text on Page ES-2, Sentence 3 will be modified to remove unintended inference to Red Fox Creek as a perennial stream. The third sentence of paragraph 2 on page ES-2 now reads, "Red Fox Creek flows throughout most of the year, which is significant in attenuating groundwater contamination discharging to the creek by the processes of dilution and volatilization."*

Comment 2) Page 1-9, Fig 1.4: Suggest depicting the fire training pit described in Section 1.4.

Parsons ES Response: *Agreed. The approximate location of the former fire-training pit will be shown on Figure 1.4.*

Comment 3) Pages 1-7 and 1-10, Sec 1.4, Para 3, Line 5: Recommend inserting "as" after "identified" to complete the sentence.

Parsons ES Response: *Agreed. The correction will be made so the sentence reads: "These contaminant concentrations are likely a result of an unidentified spill area at the RAPCON site, which was not identified as a site of concern under the Base IRP."*

Comment 4) Page 2-11, Sec 2.2: Recommend adding the screen length of the temporary monitoring points.

Parsons ES Response: *Agreed. Reference to the screen length of 0.5 feet will be added to the text. The fifth sentence of the first paragraph of Section 2.2 will read "All temporary monitoring points were screened over an interval of 0.5 feet, approximately 1 to 2 feet below the water table."*

Comment 5) Page 2-12, Sec 2.2.3, Para 1: The stated screen length, 0.5 ft, is inconsistent with screen length enumerated in Table 2.1, 1.9 ft, for temporary monitoring points. This discrepancy should be corrected.

Parsons ES Response: *Agreed. Table 2.1 will be corrected. The bottom screen interval column shown in the table is correct, whereas the top of screen interval column is inaccurate and should be 0.5 less than the bottom of screen value.*

Comment 6) Page 2-14, Sec 2.3, Para 1, Sent 2: To improve accuracy, recommend noting that metals (cations) analyses were performed for only the 1994 samples.

Parsons ES Response: *Agreed. Parsons shall add the following text to Sentence 2, Paragraph 1, Section 2.3: "...chloride, conductivity, methane, metals (September 1994 only), nitrate and nitrite,..."*

Comment 7) Page 2-16, Sec 2.3.3: Recommend adding Section 2.3.3.3 describing field alkalinity measurements.

Parsons ES Response: *Alkalinity was measured in a temporary fixed-base lab and discussion of alkalinity is not within the context of Section 2.3.3 for Onsite Chemical Parameter Measurement. Alkalinity measurements are discussed in Section 4.4.2.8.*

Comment 8) Page 3-4, Fig 3.1: Suggest adding a bar scale for horizontal distance and an insert map showing the approximate line of cross section.

Parsons ES Response: *The cross-section shown in Figure 3.1 was provided from a separate report and was reproduced to show a general layout of the major geologic intervals at King Salmon Airport. Precise well locations shown on Figure 3.1 currently are unavailable to Parsons ES, and obtaining such information would be time consuming. This figure is not essential to the argument for natural attenuation at the site and Parsons ES requests that the figure not be modified.*

Comment 9: Page 3-14, Sec 3.5, Para 2, Line 1: The typo "Airforce" needs to be corrected.

Parsons ES Response: *Agreed. Airforce shall be changed to Air Force in the text.*

Comment 10: Page 4-17, Sec 4.4:

a. Suggest that a brief discussion of general inorganic groundwater quality be added. Specifically, characterizing the groundwater in terms of major cations and anions and total dissolved solids (TDS)/electrical conductivity (EC) would be advantageous because biodegradation apparently impacts general groundwater geochemistry. For example, background EC values range from about 70 to 100 ms/cm. This increase most likely is due to dissolution of calcium carbonate naturally occurring in the aquifer.

b. Suggest adding a concise discussion of accuracy of the major cation and anion analyses for 1994 utilizing the cation-anion balance method. As a rule-of-thumb, a percent difference exceeding 10 for low-salinity water suggests a data quality problem. For 15 analyses of the ESMW series wells and MW092 and MW-94, five analyses fail this quality assurance

check (see attached summary sheets). The low alkalinity level reported for MW-4B, 9.0 mg/L, is suspect. If the hypothetical alkalinity concentration is set at 30 mg/L, percent difference approaches zero. Suggest that the text of Section 4.4.2.8 address this data quality problem with respect to accuracy of alkalinity analyses.

Parsons ES Response: *Parsons ES is appreciative of the data quality check that Mr. Atkinson performed for the data set. We concur that biodegradation dramatically changes the general groundwater geochemistry. For instance, the presence of the dissolved ferrous iron provides an additional cation in the groundwater that will add to the level of electrical conductivity.*

However, the major geochemical indicators of intrinsic remediation are the depletion of oxygen, nitrate, and sulfate and the generation of ferrous iron, manganese, methane, and carbon dioxide. Trend changes in these geochemical indicators represents actual use of electron acceptors or generation of biodegradation byproducts directly related to the biodegradation of fuel hydrocarbons (e.g., methane and CO2). Parameters such as electrical conductivity and alkalinity are affected by intrinsic remediation, but they are not an integral part (e.g., electron acceptor or metabolic byproduct) of the biodegradation reaction. Therefore, while EC and alkalinity are part of an overall argument for intrinsic remediation based on geochemical trends; they offer little by themselves to support intrinsic remediation. Therefore, Parsons requests that an in-depth analysis of EC/TDS trends and their affect on alkalinity readings not be performed, as the argument for intrinsic remediation will not be weakened by omitting this analysis.

Comment 11) Page 4-20, Fig 4.5: In the legend, for the BTEX contour entry, "mg/L" should be "ug/L."

Parsons ES Response: *Agreed. The reference to the line of equal BTEX concentration contour shall be changed from mg/L to ug/L.*

Comment 12) Pages 4-33 and 4-34, Table 4.7: Suggest adding 1994 analytical results for major cations (Ca, Mg, Na, and K).

Parsons ES Response: *Parsons ES believes that the arguments for trends in Ca, Mg, Na, and K trends in groundwater are relatively minor compared to the major geochemical indicators. For the same reasons outlined in the response to comment 11, we request that this information not be included in the text.*

Comment 13) Page 5-2, Sec 5.2, Para 1:

a. To facilitate the reader's visualization of specified-head boundaries, suggest that all model cells assigned specified heads be depicted on Figure 5-3.

b. Sent 5: The assertion that DO is being used in the anaerobic biodegradation process is false; consequently, this sentence needs to be revised accordingly.

Parsons ES Response: *a. Agreed. Specified-head boundaries will be included in Figure 5.3.*

b. Agreed. The sentence will be modified as follows, "Data and information presented in Section 4 suggest that DO, nitrate, and ferric iron are being used as the primary electron acceptors via the microbially mediated processes of aerobic respiration, denitrification, and iron reduction, respectively."

Comment 14) Page 5-7, Sec 5.3.1, Para 1, Sent 2: The drainage ditch annotated is not explicitly depicted on Figure 5.1. If the gully depicted on Figure 5.1 south of the fire training pit is the drainage ditch reference here, this fact should be stated. If not, the drainage ditch should be depicted and labeled on this figure.

Parsons ES Response: *Reference to the drainage ditch was intended to mean Red Fox Creek. Sent 2 shall be modified to, "The hydraulic head along Red Fox Creek was estimated to be 47.49 to 47.62 feet above mllw."*

Comment 15) Page 5-17, Sec 5.4.1, Para 1, Line 4: Section 3.3.2.2 is nonexistent: Section 3.4.2.2 contains hydraulic conductivity values and should be referenced here.

Parsons ES Response: *The reference to section 3.3.2.2 was incorrect and will be changed to 3.4.2.2.*

Comment 16) Pages 5-25 and 5-27, Sec 5.4.2.4: The injection well located in the model cell containing monitoring point GP-5 results in a simulated BTEX concentration more than four times the observed value. Consequently, suggest decreasing the BTEX mass injected, moving the injection well to a nearby grid cell, or both.

Parsons ES Response: *The groundwater concentrations were calibrated high, though not unreasonably so considering the size of the model grid and the relatively small source area. The model grid overlaps the 100 µg/L contour shown on Figure 4.5 and a value of 24.2 µg/L may be too low to represent BTEX concentrations throughout the model cell. Therefore, a value of 100 µg/L is considered reasonable.*

The concentration of BTEX at GP-5 is approximately two orders-of-magnitude lower than a location 150 feet to the southwest of GP-5 where BTEX concentrations are as high as 3,806 µg/L. Changing the model concentration at GP-5 would not significantly change the model calibration or the model predictions, and Parsons ES request that this work not be performed.

Comment 17) Page 6-25, Sec 6.4.1.3, Sent 2: The statement that six LTM wells will be constructed is contradictory to Table 6 which enumerates eight wells to be constructed. This inconsistency should be corrected.

Parsons ES Response: *Capital costs for eight monitoring wells were considered and the incorrect reference to six new LTM wells in Sentence 2 shall be changed to eight new LTM wells.*

Comment 18) Page 7-3, Sec 7.2, Para 2, Sent 2: The statement that MW-93 will be a background well is problematic because the sample collected in 1995 contained 10 µg/L of BTEX. Suggest, consequently, deleting "background."

Parsons ES Response: *Agreed. The reference to "background" will be changed to "upgradient."*

Comment 19) Pages 7-3 and 7-4, Sec 7.2, Para 3: The text states that a new LTM well will be constructed near monitoring point GP-7, but Figure 7.1 depicts this well near GP-8, not GP-7. This discrepancy should be resolved. Additionally, the text states that a deep well will be constructed adjacent to well FT01-FD9; however, this new well is not depicted on Figure 7.1. Recommend illustrating this proposed well on Figure 7.1

Parsons ES Response: *Agreed. The new LTM well is to be constructed near GP-8, not GP-7, and this discrepancy will be resolved. Both shallow and deep monitoring wells are to be placed on the same location of FT01-FD9, as shown on Figure 7.1.*

Comment 20) Page 7-6, Table 7.1: Suggest adding alkalinity because it is an indicator of natural attenuation and a good general water-quality parameter (major anion). Additionally, suggest adding major anions chloride and sulfate and major cations (Ca, Mg, Na, K) because they define aqueous geochemistry and allow assessment of biodegradation impacts on general groundwater geochemistry.

Parsons ES Response: *For reasons outlined in the response to comment 11, Parsons ES requests that this work not be completed.*

Comment 21) Page 8-3, Sec 8, Para 1, Sent 2: Based on statements on pages 3-1 (Sec 3.1.1) and 3-5 (Sec 3.4.1), Red Fox Creek is not a continuously flowing perennial stream as stated, neither it is an intermittent stream. Consequently, this sentence needs to be revised accordingly.

Parsons ES Response: *Agreed. The sentence that states "Red Fox Creek flows continuously throughout the year..." shall be changed to "Red Fox Creek flows throughout most of the year..."*

Comment 22) Appendix A: Recommend that field (data logger) water-level data for the slug tests be appended. This will allow for independent analysis of aquifer test data.

Parsons ES Response: *Agreed. If the slug test data are available, they will be included as a separate diskette or listing in the appendix.*

If you have any questions, have additional comments, or require additional information, please call me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

Bruce M Henry

Bruce M. Henry, P.G.
Project Manager

cc: Mr. R. Todd Herrington, Parsons ES
File 722450.11000

APPENDIX H

FINAL INTRINSIC REMEDIATION TREATABILITY STUDY ADDENDUM

FINAL
ADDENDUM TO THE TREATABILITY STUDY IN SUPPORT OF INTRINSIC REMEDIATION FOR FIRE TRAINING AREA 1 (FT01)

at

KING SALMON AIRPORT
KING SALMON, ALASKA

September 1999

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

AND

ELMENDORF AIR FORCE BASE
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ATTACHMENT A - ANALYTICAL RESULTS SEPTEMBER 1998

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
AFCEE	Air Force Center for Environmental Excellence
AST	aboveground storage tank
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
$CaCO_3$	calcium carbonate
CAHs	chlorinated aliphatic hydrocarbons
CO_2	carbon dioxide
cy	cubic yard
DO	dissolved oxygen
EMCON	EMCON Alaska, Inc.
ES	Engineering Science, Inc. (now known as Parsons Engineering Science, Inc.)
Fe^{2+}	ferrous iron
Fe^{3+}	ferric iron
ft/day	feet per day
ft/ft	foot per foot
FT01	Fire Training Area 1
IRP	Installation Restoration Program
KSA	King Salmon Airport
LNAPL	light non-aqueous phase liquid
LTM	long-term monitoring
mg/L	milligrams per liter
MTBE	methyl tert-butyl ether
mV	millivolts
NRMRL	National Risk Management Research Laboratory
ORP	oxidation-reduction potential
Parsons ES	Parsons Engineering Science, Inc.
redox	reduction-oxidation
RI/FS	remedial investigation/feasibility study
SAIC	Science Applications International Corporation
TEMBs	tetramethlybenzenes
TMBs	trimethylbenzenes
TOC	total organic carbon
TS	treatability study
USAF	United States Air Force
USEPA	US Environmental Protection Agency
UST	underground storage tank

1.0 INTRODUCTION

This treatability study (TS) addendum was prepared for the Air Force Center for Environmental Excellence (AFCEE) by Parsons Engineering Science, Inc. (Parsons ES) as an update to the Draft TS in Support of Intrinsic Remediation (Parsons ES, 1996) previously conducted to evaluate intrinsic remediation for Fire Training Area 1 (FT01) at the King Salmon Airport, King Salmon, Alaska. Sampling events were conducted in September 1994 and July 1995 to evaluate the use of intrinsic remediation for remediation of groundwater contaminated by petroleum hydrocarbons. This addendum summarizes the results of a third sampling event conducted in September 1998 as part of the continuing evaluation of intrinsic remediation at the site. Additional data collected by the United States Air Force (USAF) in September 1996 also are included for evaluation (USAF, 1997). Results and predictions presented in the TS (Parsons ES, 1996) are used as the basis for comparison.

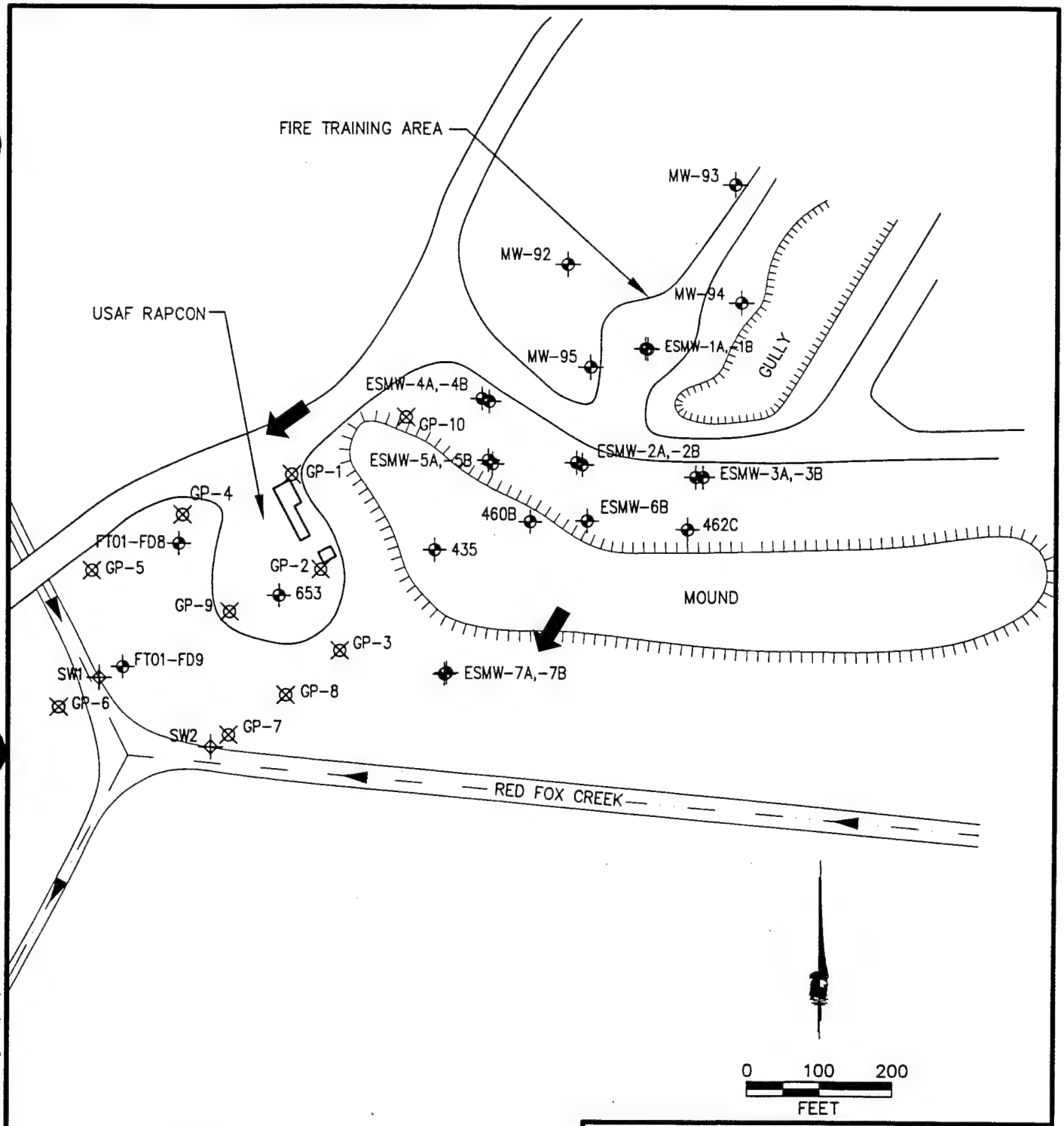
In the TS, comparison of benzene, toluene, ethylbenzene, and xylenes (BTEX), electron acceptor, and biodegradation byproduct isopleth maps for FT01 indicated strong qualitative evidence of BTEX biodegradation. Geochemical data strongly suggested that aerobic respiration, denitrification, and iron reduction are the primary biological mechanisms responsible for BTEX biodegradation. Patterns observed in the distribution of fuel hydrocarbons, electron acceptors, and biodegradation byproducts further indicated that biodegradation was reducing dissolved BTEX concentrations in site groundwater. Natural attenuation is currently the only process acting to reduce source and dissolved contaminant mass at the site.

1.1 Scope and Objectives

The primary objective of this addendum is to evaluate changes in concentrations of dissolved BTEX, BTEX plume extent, and other natural attenuation trends between September 1994 and September 1998. The most comprehensive analytical data set for FT01 was collected in July 1995 and this data is used as a baseline for comparison of the most recent September 1998 data. In September 1998, groundwater samples were collected from 7 existing monitoring wells by researchers from the United States Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRMRL) Subsurface Protection and Remediation Division. Data from September 1994 is included in this addendum to provide a broader historical database for analysis of natural attenuation trends.

1.2 Site Background

Site FT01 is located in the east-central portion of King Salmon Airport (KSA), approximately 2,000 feet east/northeast of the intersection of the main runways. The fire training area was used from 1980 to 1992 for fire training exercises that involved the use of fuels, solvents, oils, and fire retardant chemicals (EMCON, Alaska, Inc. [EMCON], 1994). The main feature is an unlined, circular pit approximately 50 feet in diameter and is hydraulically upgradient from Red Fox Creek (Figure 1). For the purposes of this addendum, Site FT01 refers to an area that includes the former fire training area and the plume of fuel-hydrocarbon-contaminated groundwater extending southwest as far as Red Fox Creek.



LEGEND

MW-92 — MONITORING WELL INSTALLED

SW1 — SURFACE WATER SAMPLING LOCATION

GP-1 — TEMPORARY MONITORING WELL (JULY 1995)

ESTIMATED GROUNDWATER FLOW DIRECTION

FIGURE 1

SITE FEATURES MAP

Fire Training Area 1 (FT01)
Intrinsic Remediation TS Addendum
King Salmon Airport, Alaska

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The site was identified as potentially contaminated in 1985 under the Base installation restoration program (IRP) (Engineering-Science, Inc. [ES], 1985). Historical information indicates that the contamination was introduced into the subsurface at the fire training area beginning in 1980. The majority of the contaminated soils at FT01 were excavated in 1995 (EMCON, 1996).

Mobile light nonaqueous-phase liquid (LNAPL) has never been detected in monitoring wells at Site FT01. However, a hydrocarbon sheen was reportedly observed in Red Fox Creek and in subsurface soils near Red Fox Creek at monitoring well FT01-FD9. An approximately 0.25-inch-thick-layer of mobile LNAPL also was noted on the groundwater surface in the fire training pit excavation in 1995. Residual LNAPL in soils not excavated in 1995 at Site FT01 likely provide a continuing source of dissolved BTEX, and may increase the time required to remediate groundwater at the site. Because Site FT01 is inactive, additional fuel releases are not expected.

An aboveground storage tank (AST) was removed from the site on an undetermined date (Science Applications International Corporation [SAIC], 1993). Probable sources of contamination include fuel and solvent storage prior to use in fire training activities, transfer of fuels and solvents to the fire training pit, and incomplete combustion of fuels and solvents during fire training exercises. Soil and groundwater fuel contamination was first confirmed during and airport-wide preliminary remedial investigation/feasibility study (RI/FS) involving 11 sites, including Site FT01 (SAIC, 1993). Soil and groundwater samples were collected by EMCON in October 1993 to supplement RI/FS field investigation results. Residual LNAPL was detected in soil samples. These results suggested possible migration of the groundwater plume to Red Fox Creek.

Two tanks with unknown contents, one a 500 gallon-underground storage tank (UST), and the other a 2,000-gallon AST were removed on unknown dates, and are the probable source of soil and groundwater contamination at the RAPCON site (Figure 1). The RAPCON site was included in the scope of work for the TS because groundwater contamination from Site FT01 commingles with groundwater contamination from the RAPCON site. However, groundwater samples were only collected from monitoring wells directly associated with Site FT01 for this addendum. Therefore, the RAPCON site is not addressed herein.

Approximately 2,025 cubic yards (cy) of contaminated soil was excavated and removed from Site FT01 between June 27 and August 1, 1995 (EMCON, 1996). This effectively removed most petroleum-impacted soils from the vadose zone (EMCON, 1996). A 70-foot diameter area of soil was excavated from the fire pit to a depth of 10 feet below ground surface (bgs). Both petroleum and dioxin contaminated soils were removed. However, confirmation samples showed that the bottom of the excavation still contained high levels of fuel constituents. Excavation was continued to 12 feet bgs, at which depth groundwater was encountered at the bottom of the excavation. The excavation was then terminated. The excavation activities are documented in the *Source Investigation and Removal Action* report (USAF, 1995).

2.0 MONITORING RESULTS

In September 1998, researchers from the USEPA NRMRL collected groundwater samples from 7 monitoring wells at Site FT01. Prior to purging and sampling each well, groundwater levels were measured to the nearest 0.1 foot. Groundwater samples were analyzed in the field for dissolved oxygen (DO), temperature, pH, conductivity, oxidation-reduction potential (ORP), alkalinity, sulfate, carbon dioxide (CO_2), sulfide, and ferrous iron (Fe^{2+}). Additional sample volume was analyzed at the USEPA NRMRL in Ada, Oklahoma, for BTEX, trimethylbenzenes (TMBs), methyl tert-butyl ether (MTBE), naphthalene, total fuel carbon, chlorinated aliphatic hydrocarbons (CAHs), chlorobenzenes, methane, ethane, ethene, nitrate+nitrite (as nitrogen), ammonia, chlorides, total organic carbon (TOC), and sulfate. Analytical methods used are summarized in Table 1.

2.1 Flow Direction and Gradient

Depth to groundwater was measured in all of the wells sampled in September 1998. Table 2 includes groundwater elevations for September 1994, July 1995, and September 1998. Contour maps of shallow groundwater elevations for September 1994, July 1995, September 1996 (USAF, 1997), and September 1998 are presented on Figure 2. Because some wells are clustered and screened in deeper aquifer intervals, only wells reflecting the shallowest groundwater elevation were used to construct contour intervals on Figure 2. The predominant direction of shallow groundwater flow at Site FT01 is to the south/southwest toward Red Fox Creek.

Of the 7 wells at which groundwater elevations were measured in September 1998, the same wells were also measured in September 1995, and 5 of the 7 wells were measured in July 1995. Of these 7 wells, water elevations decreased in 6, and increased in 1 between 1994 and 1998. The decrease in water table elevation ranged from 0.61 foot (ESMW-4A) to 3.09 feet (ESMW-1A). Changes in groundwater elevation may be attributed to seasonal or annual variations in recharge (precipitation).

The average hydraulic gradient in July 1995 at Site FT01 was approximately 0.005 foot per foot (ft/ft) (Parsons ES, 1996). In September 1998, the average gradient along the same flow path was approximately 0.003 ft/ft.

An average hydraulic conductivity of 59 feet per day (ft/day) and an effective porosity of 0.25 were used to calculate an average groundwater advective velocity for Site FT01 in July 1995. The average advective groundwater velocity using the average hydraulic gradients above were calculated to be 1.18 ft/day (431 feet per year [ft/yr]) in July 1995, and 0.71 ft/day (258 ft/yr) in September 1998.

Vertical gradients also were calculated for Site FT01 in July 1995. Vertical groundwater gradients were low in 1995, with a downward gradient of 0.004 ft/ft at well pair ESMW-4A and B, and a downward gradient of 0.005 ft/ft at well pair ESMW-5A and B. Due to a lack of water levels collected at appropriate wells in September 1994 and September 1998, vertical gradients could not be calculated for these dates.

TABLE 1
SUMMARY OF GROUNDWATER ANALYTICAL METHODS
SEPTEMBER 1998
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Analyte	Method	Field (F) or Fixed-Base Laboratory (L)
Oxidation\Reduction Potential	Direct Reading Meter	F
Dissolved Oxygen	Direct Reading Meter	F
Conductivity	Direct Reading Meter	F
Temperature	Direct Reading Meter	F
pH	Direct Reading Meter	F
Ferrous Iron (Fe^{2+})	Colorimetric, Hach Method 8146 or equivalent	F
Hydrogen Sulfide	Colorimetric, Hach Method 8131 or equivalent	F
Sulfate	Colorimetric, Hach Method 8051 or equivalent	F
Carbon Dioxide	Titrimetric, Hach Method 1436-01 or equivalent	F
Alkalinity (Carbonate [CO_3^{2-}] and Bicarbonate [HCO_3^-])	Titrimetric, Hach Method 8221 or equivalent	F
Nitrate + Nitrite	Lachat FIA Method 10-107-04-2-A	L
Ammonia	Lachat FIA Method 10-107-06-1-A	L
Chloride	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethane and Ethene	RSKSOP-175[a/] and RSKSOP-194	L
BTEX, TMBs, MTBE, Naphthalene, and Total Fuel Carbon	RSKSOP-133	L
CAHs and Chlorobenzenes	RSKSOP-148	L
TOC	RSKSOP-102	L

[a/] RSKSOP = Robert S. Kerr Laboratory (now known as NRMRL) standard operating procedure.

TABLE 2
WATER LEVEL ELEVATION DATA
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Well Designation	Date	Datum Elevation (mllw)[a]	Ground Elevation (mllw)	Screen Interval		Total Depth to Water (ft bgs)	Total Depth to Water (ft btoc)[c]	Elevation of Water Table (mllw)
				Top (ft bgs)[b]	Bottom (ft bgs)			
ESMW-1A	9/94	62.89	60.5	13.0	18.0	11.31	13.71	49.18
ESMW-1A	7/95	62.89	60.5	13.0	18.0	13.30	15.70	47.19
ESMW-1A	9/98	62.89	60.5	13.0	18.0	14.40	16.80	46.09
ESMW-1B	9/94	62.98	60.5	31.1	38.1	11.32	13.81	49.17
ESMW-1B	9/98	62.98	60.5	31.1	38.1	14.31	16.80	46.18
ESMW-2A	9/94	63.80	61.1	13.0	18.0	12.91	15.62	48.18
ESMW-2A	7/95	63.80	61.1	13.0	18.0	14.33	17.04	46.76
ESMW-2A	9/98	63.80	61.1	13.0	18.0	15.49	18.20	45.60
ESMW-2B	9/94	63.77	61.1	35.0	40.0	12.92	15.60	48.17
ESMW-2B	7/95	63.77	61.1	35.0	40.0	14.32	17.00	46.77
ESMW-3A	9/94	62.85	60.5	12.0	17.0	11.95	14.31	48.54
ESMW-3A	9/98	62.85	60.5	12.0	17.0	14.54	16.90	45.95
ESMW-3B	9/94	63.41	60.5	33.2	38.2	11.92	14.84	48.57
ESMW-4A	9/94	63.71	61.0	13.0	18.0	12.77	15.49	48.22
ESMW-4A	7/95	63.71	61.0	13.0	18.0	14.23	16.95	46.76
ESMW-4A	9/98	63.71	61.0	13.0	18.0	13.38	16.10	47.61
ESMW-4B	9/94	63.64	61.0	32.0	37.0	12.83	15.48	48.16
ESMW-4B	7/95	63.64	61.0	32.0	37.0	14.28	16.93	46.71
ESMW-5A	9/94	54.57	51.9	4.0	9.0	4.07	6.75	47.82
ESMW-5A	7/95	54.57	51.9	4.0	9.0	5.48	8.16	46.41
ESMW-5A	9/98	54.57	51.9	4.0	9.0	3.52	6.20	48.37
ESMW-5B	9/94	55.02	51.9	22.1	27.1	4.02	7.15	47.87
ESMW-5B	7/95	55.02	51.9	22.1	27.1	5.41	8.54	46.48
ESMW-6B	9/94	55.70	53.0	23.0	28.0	5.13	7.84	47.86
ESMW-6B	7/95	55.70	53.0	23.0	28.0	6.43	9.14	46.56
ESMW-7A	9/94	60.15	57.1	8.0	13.0	9.22	12.28	47.87
ESMW-7B	9/94	59.69	56.9	25.5	30.5	31.00	11.83	47.86
MW-92	7/95	65.54	63.9	9.0	29.0	14.69	16.34	49.20
MW-92	7/95	65.54	63.9	9.0	29.0	16.27	17.92	47.62
MW-93	9/94	61.46	59.5	5.0	25.0	9.19	11.16	50.30
MW-93	7/95	61.46	59.5	5.0	25.0	10.89	12.86	48.60
MW-94	9/94	61.27	59.2	6.0	26.0	9.31	11.39	49.88
MW-94	7/95	61.27	59.2	6.0	26.0	11.04	13.12	48.15
MW-95	9/94	61.16	59.2	7.5	27.5	10.38	12.35	48.81
MW-95	7/95	61.16	59.2	7.5	27.5	11.89	13.86	47.30
MW-95	9/98	61.16	59.2	7.5	27.5	13.13	15.10	46.06
EMCON-1	7/95	N/A[d]	N/A	3.0	13.0	N/A	7.98	N/A
EMCON-2	7/95	N/A	N/A	3.0	13.0	N/A	11.71	N/A
435	9/94	66.84	64.5	15.0	25.0	15.88	18.23	48.61
435	7/95	66.84	64.5	15.0	25.0	17.15	19.50	47.34
460B	9/94	62.07	59.2	9.0	19.0	11.54	14.42	47.65
460B	7/95	62.07	59.2	9.0	19.0	12.84	15.72	46.35
462C	9/94	53.56	52.1	4.0	14.0	3.96	5.43	48.13
462C	7/95	53.56	52.1	4.0	14.0	5.21	6.68	46.88
653	9/94	60.00	57.2	9.5	19.5	9.30	12.11	47.89
653	7/95	60.00	57.2	9.5	19.5	10.53	13.34	46.66

[a] ft mllw = Feet above mean lower low water level.

[b] ft bgs = Feet below ground surface.

[c] ft btoc = Feet below top of casing.

[d] N/A = Data not available.

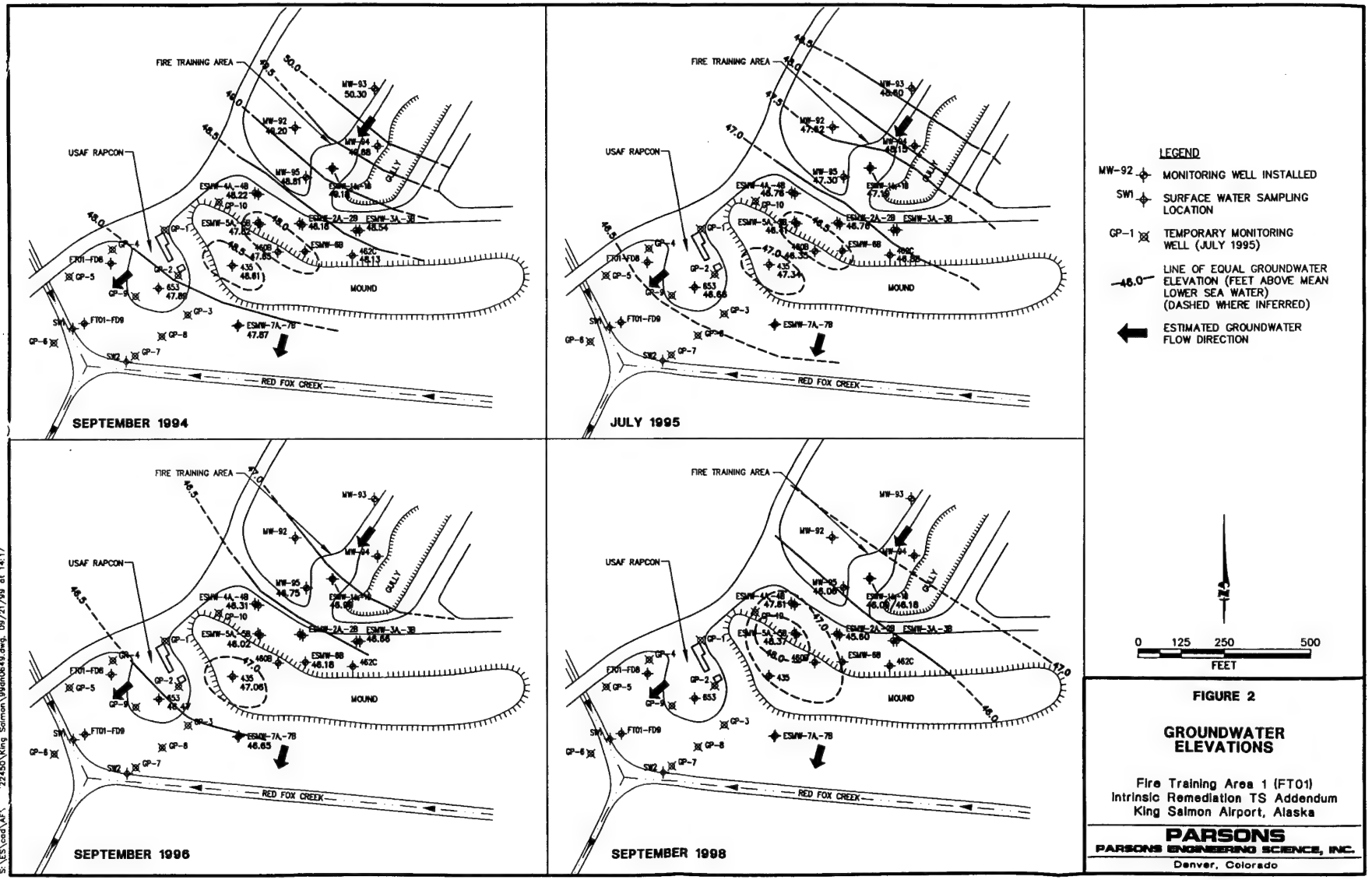

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FIGURE 2

GROUNDWATER ELEVATIONS

Fire Training Area 1 (FT01)
Intrinsic Remediation TS Addendum
King Salmon Airport, Alaska

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Denver, Colorado

2.2 Total BTEX in Groundwater

BTEX compounds were detected in groundwater samples from 5 of the 7 monitoring wells sampled in September 1998. BTEX concentrations in groundwater are summarized in Table 3. In order to evaluate trends in BTEX concentrations and distribution through time, the areal distributions of total BTEX in shallow groundwater for September 1994, July 1995, September 1996, and September 1998 are presented on Figure 3. For all clustered well locations, the sample from the shallow well had the highest BTEX concentration relative to deeper well pairs. Therefore, where there were multiple BTEX concentrations at a well cluster, the shallow well concentration was used to plot BTEX isopleths on Figure 3.

The downgradient extent of the BTEX plume was not delineated in September 1998. Perimeter monitoring well locations ESMW-2A, ESMW-3A, and ESMW-4A to the east and west of the groundwater plume center exhibited low BTEX concentrations ranging from non-detect to 0.9 micrograms per liter (µg/L) in July 1995. In September 1998, these same locations all had BTEX concentrations below the limit of quantification (i.e., less than 1 µg/L).

Changes in BTEX concentrations over time in monitoring wells ESMW-1A, ESMW-5A, MW-95, 435, and ESMW-1B from September 1994 to September 1998 are presented on Figure 4. Monitoring well ESMW-1A, located in the FT01 source area, exhibited the highest BTEX concentration in July 1995 at 4,514 µg/L (after source excavation activities), while in 1998 the BTEX concentration at ESWM-1A decreased to 2,088 µg/L. Because groundwater BTEX concentrations have steadily decreased in the source area since July 1995, it appears that source removal in 1995 has reduced BTEX mass flux to groundwater.

Contrary to source area well ESMW-1A, BTEX concentrations at monitoring well ESMW-5A have increased after July 1995. Total BTEX concentrations at ESMW-5A increased from 85.5 µg/L in 1995, to 943 µg/L in 1996 and 1,123 µg/L in 1998. The increase in BTEX concentrations at ESMW-5A (located along the approximate centerline of the plume) suggest that a slug of BTEX contamination may be migrating downgradient from the source area. It is plausible that source excavation in 1995 caused a temporary increase in BTEX mass flux to groundwater due to disturbance and mobilization of LNAPL in soils near the water table in the former fire training pit. As the groundwater BTEX slug migrates, disperses, and degrades along the plume axis, the plume should stabilize in a steady-state configuration.

With the exception of well ESMW-5A, overall groundwater BTEX concentrations are stable or decreasing at Site FT01, suggesting that source removal has been effective in helping to stabilize the BTEX plume.

Total BTEX versus distance from the source area for wells ESMW-1A, MW-95, 435, and ESMW-5A are plotted on Figure 5. Although BTEX concentrations increased in the downgradient portion of the plume as the possible result of a migrating slug of dissolved BTEX contamination, the decrease in 1998 BTEX concentrations at wells ESMW-1A and MW-95 suggest that biodegradation continues to limit plume expansion.

TABLE 3
FUEL HYDROCARBON COMPOUNDS AND MTBE[a] DETECTED IN GROUNDWATER AND SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Sample Location	Date	TPH[b] (as Fuel Carbon) (µg/L)[d]	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX[c] (µg/L)	Naphthalene (µg/L)	MTBE (µg/L)
ESMW-1A	9/94	10,100	1,050	6,470	358	398	1,170	690	2,258	10,136	NA[e]	NA
ESMW-1A	7/95	8,980	796	5,400	399	371	1,030	619	2,020	8,615	69.0	NA
ESMW-1A	9/96	NR[f]	432 Y[g]	2,620 Y	205 Y	898 Y	**[h]	359 Y	1,257 Y	4,514 Y	NA	NA
ESMW-1A	9/98	2,624	75.2	ND	276	306	961	470	1,737	2,088	59.7	14
ESMW-1B	9/94	1,850	5.6	59.1	20.9	28.9	87.2	36.6	152.7	238.3	NA	NA
ESMW-1B	7/95	4.8	<1	1.2	ND[i]	ND	<1	<1	<2	1.2	<10	NA
ESMW-1B	9/96	NR	ND	0.13	0.037 J[j]	0.14	**	ND	0.14	0.3	NA	NA
ESMW-1B	9/98	3.0	ND	1.8	ND	ND	1.1	ND	1.1	2.9	ND	ND
ESMW-2A	9/94	12.1	ND	9.0	<1	<1	2.5	1.4	3.9	12.9	NA	NA
ESMW-2A	7/95	1.2	ND	0.9	ND	ND	<1	ND	<1	0.9	ND	NA
ESMW-2A	9/98	ND	ND	0.6	ND	ND	ND	ND	0.0	0.6	ND	ND
ESMW-2B	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
ESMW-2B	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
ESMW-3A	9/94	17.5	0.9	13.0	<1	1.0	2.7	1.5	5.2	19.1	NA	NA
ESMW-3A	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
ESMW-3A	9/96	NR	ND	0.26	ND	0.11	**	ND	0.11	0.4	NA	NA
ESMW-3A	9/98	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ESMW-3B	9/94	<1	ND	<1	ND	<1	<1	ND	<2	<3	NA	NA
ESMW-3B	9/96	NR	ND Y	0.2 Y	ND Y	0.54 Y	**	.16 Y	.70 Y	.90 Y	NA	NA
ESMW-4A	9/94	4.6	ND	3.0	ND	ND	1.3	<1	1.3	4.3	NA	NA
ESMW-4A	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
ESMW-4A	9/96	NR	ND	ND	ND	ND	**	ND	ND	ND	NA	NA
ESMW-4A	9/98	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ESMW-4B	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
ESMW-4B	9/96	NR	ND	ND	ND	ND	**	ND	ND	ND	NA	NA

TABLE 3 (Continued)
FUEL HYDROCARBON COMPOUNDS AND MTBE[a/] DETECTED IN GROUNDWATER AND SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Sample Location	Date	TPH[b/] (as Fuel Carbon) (µg/L)[d/]	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX[c/] (µg/L)	Naphthalene (µg/L)	MTBE (µg/L)
ESMW-5A	9/94	1,270	45.5	8.1	38.5	165	139	318	622	714	NA	NA
ESMW-5A	7/95	275	14.3	16.8	7.6	20.4	11.6	14.8	46.8	85.5	21.3	NA
ESMW-5A	9/96	NR	327	128	81.1	280	**	127	407	943	NA	NA
ESMW-5A	9/98	1,574	419	3.4	99.8	148	271	181	600	1,122	30.5	13.9
ESMW-5B	9/94	27.4	ND	ND	0.9	ND	<1	ND	<1	0.9	NA	NA
ESMW-5B	7/95	1.3	<1	ND	0.9	ND	ND	ND	ND	0.9	ND	NA
ESMW-5B	9/96	NR	ND	0.1	0.0884 J	ND	**	ND	ND	0.2 J	NA	NA
ESMW-6B	9/94	2.2	ND	1.7	ND	ND	<1	ND	<1	1.7	NA	NA
ESMW-6B	7/95	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
ESMW-6B	9/96	NR	ND	0.2	ND	0.09 J	**	ND	0.09 J	0.3 J	NA	NA
ESMW-7A	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
ESMW-7A	9/96	NR	ND	ND	ND	ND	**	ND	ND	ND	NA	NA
ESMW-7B	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
ESMW-7B	9/96	NR	ND	ND	ND	ND	**	ND	ND	ND	NA	NA
FT01-FD9	7/95	6,680	319	755	456	448	1,130	698	2,276	3,806	230	NA
FT01-FD9	9/96	NR	425 Y	370 Y	253 Y	982 Y	**	303 Y	1,285 Y	2,333 Y	NA	NA
FT01-FD8	7/95	5.8	<1	4.1	<1	<1	<1	<1	<3	4.1	ND	NA
FT01-FD8	9/96	NR	ND Y	ND Y	ND Y	ND Y	**	ND Y	ND Y	ND Y	NA	NA
MW-92	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
MW-92	7/95	3.2	ND	2.5	ND	ND	<1	ND	<1	2.5	ND	NA
MW-93	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
MW-93	7/95	20.2	<1	5.6	<1	0.9	2.2	1.4	4.5	10.1	ND	NA
MW-94	9/94	<1	ND	ND	ND	<1	ND	ND	<1	<1	NA	NA
MW-94	7/95	<1	ND	<1	ND	ND	ND	ND	ND	<1	ND	NA

TABLE 3 (Continued)
FUEL HYDROCARBON COMPOUNDS AND MTBE[a/] DETECTED IN GROUNDWATER AND SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Sample Location	Date	TPH[b/] (as Fuel Carbon) (µg/L)[d/]	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX[c/] (µg/L)	Naphthalene (µg/L)	MTBE (µg/L)
MW-95	9/94	876	180	470	32.7	38.8	106	66.0	211	894	NA	NA
MW-95	7/95	2,240	349	1,010	90.3	99.0	290	180	569	2,018	25.4	NA
MW-95	9/96	NR	194	616	55.6	294	**	123	417	1,283	NA	NA
MW-95	9/98	1338	68.3	611	63.6	84.2	221	122	427	1,170	20.8	ND
435	9/94	795	58.6	7.1	67.6	93.3	138.0	125.0	356.3	489.6	NA[b/]	NA
435	7/95	241	28.2	1.4	17.7	31.7	ND[c/]	2.2	33.9	81.2	13.1	NA
435	9/96	NR	570 Y	20.7 Y	94.6 Y	371 Y	**	209 Y	580 Y	1,265 Y	NA	NA
653*	7/94	NA	330	1,500	180	870	NA	390	1,260	3,270	NA	NA
653	7/95	4,480 J	357	1420 J	200	210	559	385	1,154	3,131	127	NA
653	9/96	NR	63.8	361	54.8	228	**	91.7	320	799	NA	NA
460B	9/94	<1	ND	<1	ND	ND	ND	ND	ND	<1	NA	NA
460B	7/95	8.0	<1	4.1	<1	<1	<1	<1	<3	4.1	ND	NA
462C	9/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
462C	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
GP-1	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
GP-2	7/95	<1	ND	<1	<1	<1	<1	ND	<2	<4	ND	NA
GP-3	7/95	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GP-3	9/96	NR	0.6	ND	ND	ND	**	ND	ND	0.6	NA	NA
GP-4	7/95	8.5	<1	1.3	0.9	1.0	2.0	1.3	4.3	6.5	ND	NA
GP-5	7/95	37.3	2.0	4.7	2.9	3.0	7.1	4.5	14.6	24.2	ND	NA
GP-5	9/96	NR	ND	0.4	ND	ND	**	ND	ND	0.4	NA	NA
GP-6	7/95	24.7	2.2	1.6	1.0	1.0	2.3	1.5	4.8	9.6	ND	NA
GP-6	9/96	NR	371	3.0	145	91.7	**	160	252	771	NA	NA
GP-7	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
GP-8	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

TABLE 3 (Continued)
FUEL HYDROCARBON COMPOUNDS AND MTBE[a/] DETECTED IN GROUNDWATER AND SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Sample Location	Date	TPH[b/] (as Fuel Carbon) (µg/L)[d/]	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX[c/] (µg/L)	Naphthalene (µg/L)	MTBE (µg/L)
GP-9	7/95	12,800 J	1050	4150 J	706	679	1,760	880	3,319	9,225	366	NA
GP-9	9/96	NR	1,430 Y	8,190 Y	499 Y	2,450 Y	**	991 Y	3,441 Y	13,560 Y	NA	NA
GP-10	7/95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
SW-01	7/95	772	94.8	52.0	44.3	56.6	64.5	40.0	161.1	352.2	21.6	NA
SW-02	7/95	7.6	4.8	3.5	ND	ND	<1	ND	<1	8.3	<10	NA

[a/] MTBE = Methyl Tertiary-Butyl Ether.

[b/] Fuel Carbon = Total Petroleum Hydrocarbons (TPH) (normalized for JP-4) x 0.85.

[c/] BTEX = Benzene, Toluene, Ethylbenzene, and Xylenes.

[d/] µg/L = micrograms per liter.

[e/] NA = Not Analyzed.

[f/] NR = TPH Not Recorded as Total Fuel Carbon.

[g/] Y = Indicates sample was received by the laboratory at a pH greater than 2.

[h/] ** Reported as m&p Xylenes.

[i/] ND = Not Detected.

[j/] J = Laboratory estimate.

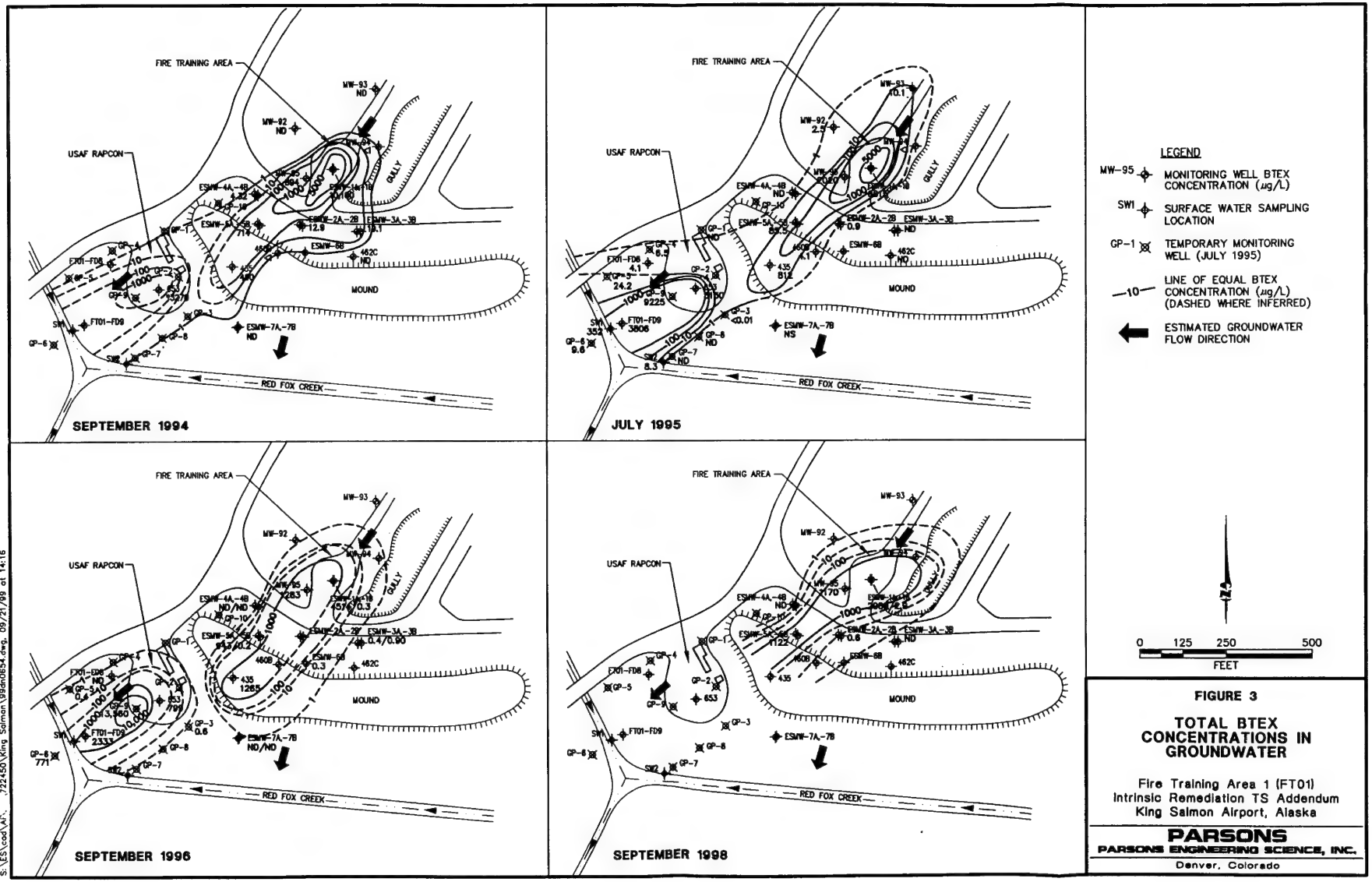

FIGURE 3

TOTAL BTEX CONCENTRATIONS IN GROUNDWATER

Fire Training Area 1 (FT01)
Intrinsic Remediation TS Addendum
King Salmon Airport, Alaska

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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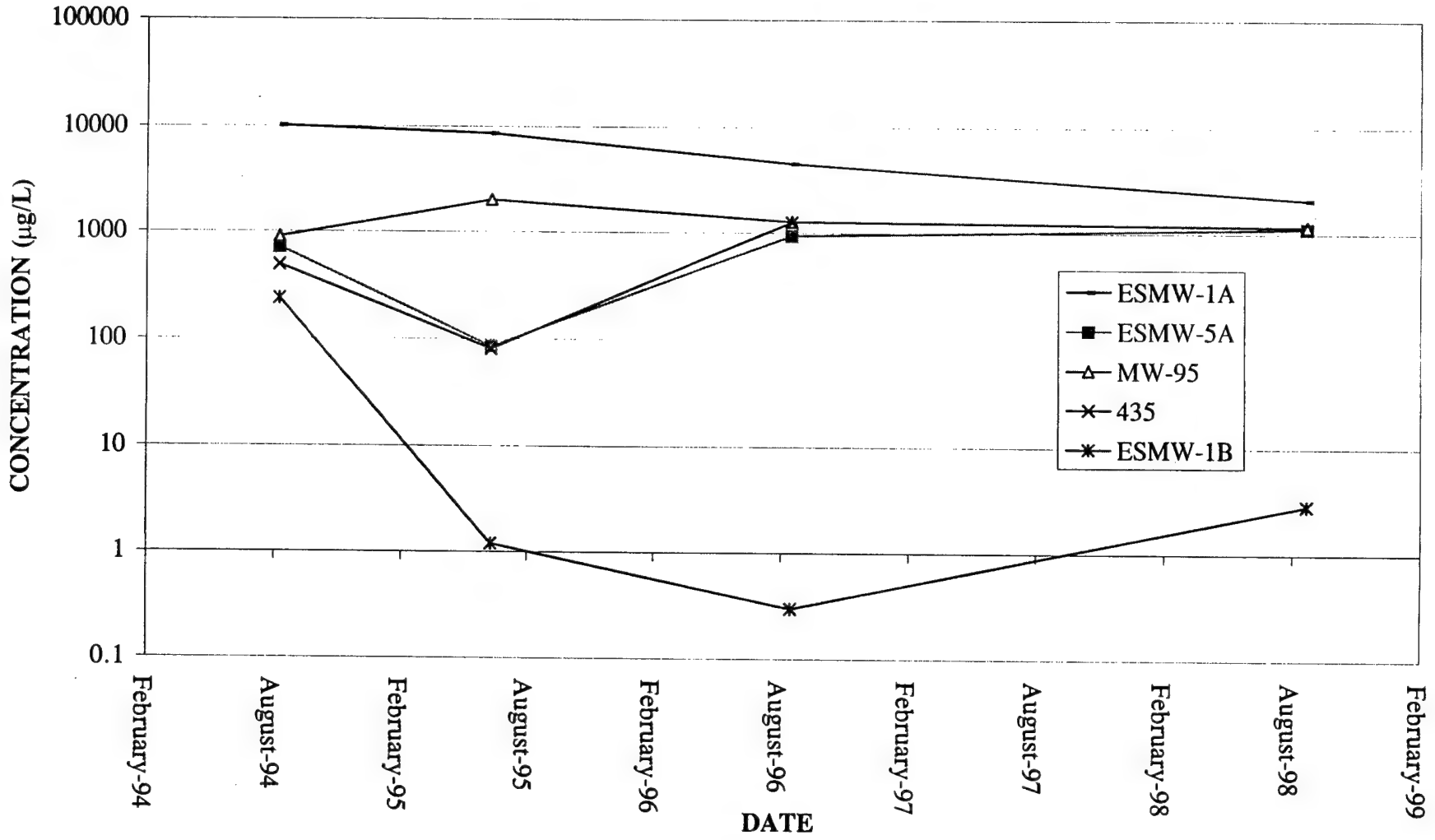
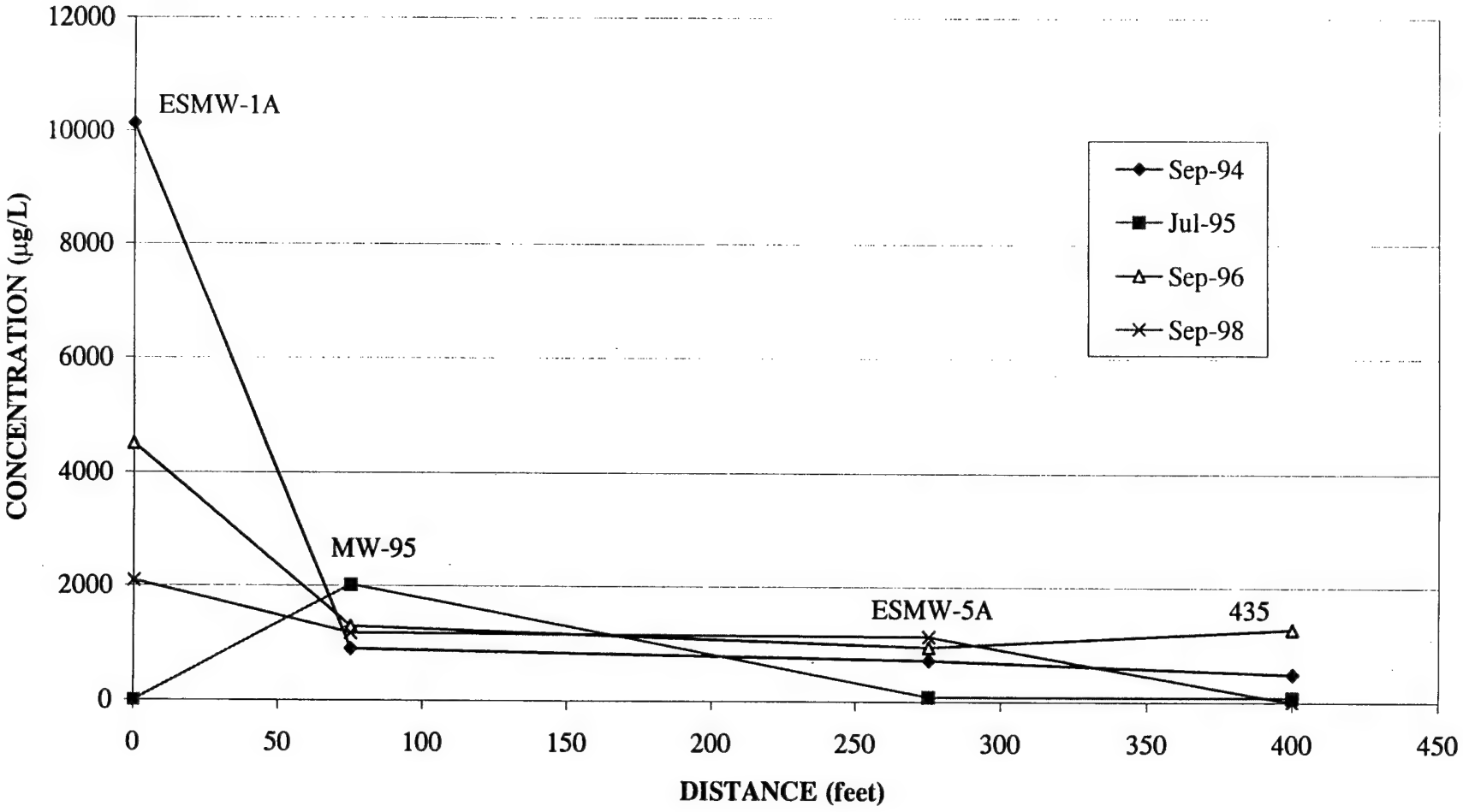
FIGURE 4
TOTAL BTEX VERSUS TIME AT SELECTED MONITORING WELLS
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA



022/722450/kingsalmon/2.xls/TOTAL BTEX

FIGURE 5
TOTAL BTEX VERSUS DISTANCE FROM SOURCE AREA
(ESMW-1A > MW-95 > ESMW-5A > 435)
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA



022/722450/kingsalmon/2.xls/distvsbtex

The observed BTEX plume at Site FT01 can not be compared to that predicted by the Bioplume II model presented in the TS, because the downgradient extent of the September 1998 BTEX plume was not delineated. Model simulation with Bioplume II assumed excavation of the source area in 1995, as well as natural attenuation mechanisms degrading the BTEX plume. Results of this simulation predicted that the plume at Site FT01 would remain relatively stable, and be completely biodegraded after year 2007. Given an average advective groundwater velocity of approximately 258 ft/yr (based on the 1998 average hydraulic gradient) and an estimated retardation coefficient for benzene of 1.10 (Parsons ES, 1996), the BTEX plume potentially could have migrated an estimated 700 feet in the three years between the July 1995 and September 1998 if biodegradation was not occurring.

2.3 Benzene in Groundwater

Of the four compounds that comprise BTEX, benzene is the primary risk driver at the study area due to its higher chemical toxicity and corresponding lower regulatory action concentration. Figure 6 plots benzene concentrations over time at select wells that are representative of conditions near the source area at Site FT01 (ESMW-1A and MW-95), and downgradient along the axis of the benzene plume (ESMW-5A and 435).

Benzene concentrations have decreased in source area wells ESMW-1A and MW-95. Benzene concentrations for ESMW-1A decreased from 796 µg/L in July 1995 to 75.2 µg/L in September 1998, and from 349 µg/L in July 1995 to 68.3 µg/L in September 1998 for well MW-95. Along the plume axis, benzene has increased in concentration at well ESMW-5A (from 275 µg/L in July 1995 to 1,574 µg/L in September 1998). Monitoring well 435 was not sampled in September 1998. Trends in benzene concentrations are similar to those for total BTEX as discussed above.

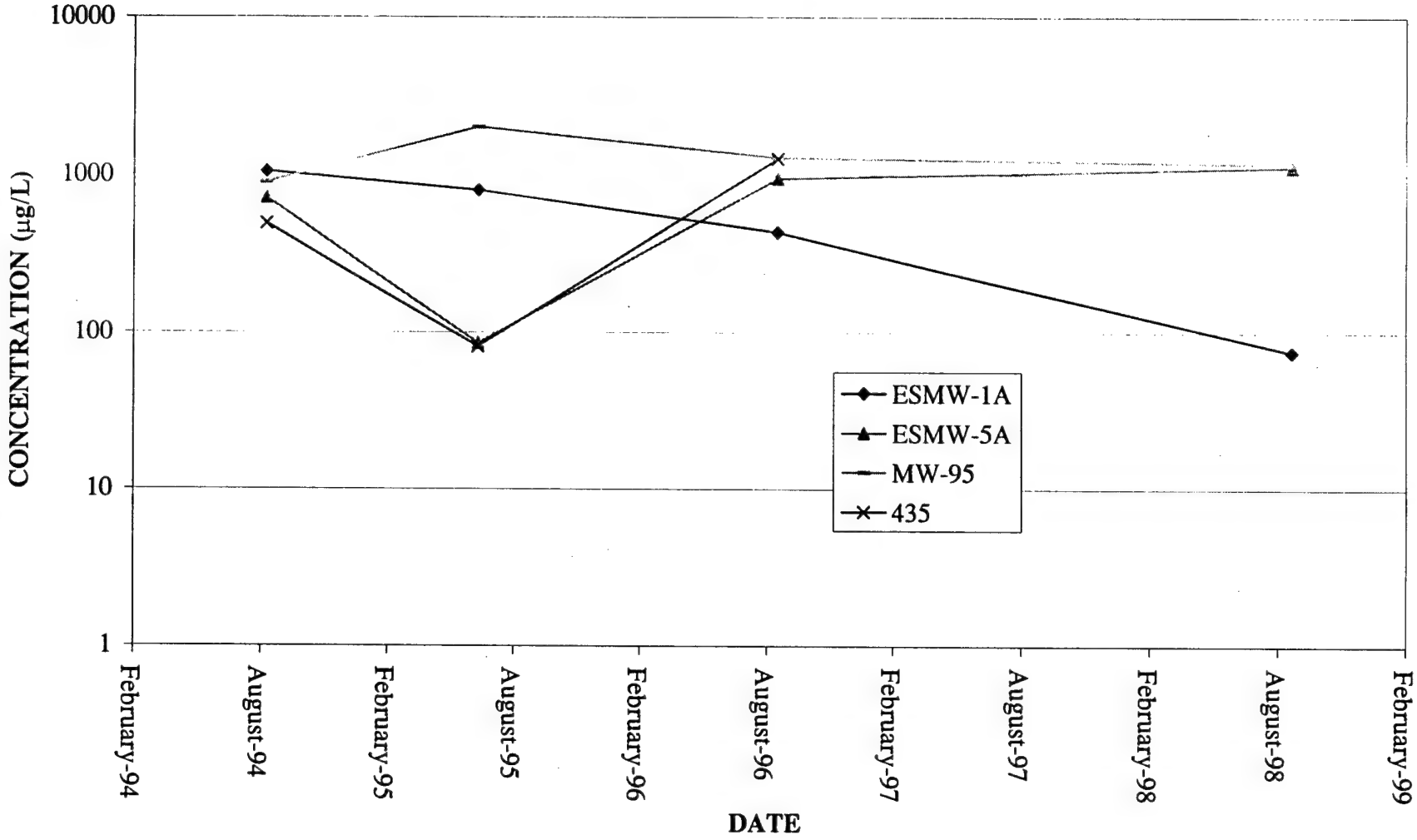
2.4 MTBE in Groundwater

Groundwater samples collected during the September 1998 sampling event were analyzed for MTBE for the first time and are shown on Table 3. MTBE is a fuel oxygenate added to fuel to increase the octane rating and to reduce combustion emissions. MTBE typically migrates at a faster rate than fuel hydrocarbons in groundwater due to a relatively lower affinity for soil sorption (retardation). Although no historical site data exist for MTBE, the greatest concentrations of MTBE were detected in groundwater samples collected from the BTEX plume interior and directly downgradient. MTBE was only detected in 2 of the 7 wells at a concentration of 14.0 µg/L for ESMW-1A and 13.9 µg/L for ESMW-5A. MTBE was likely introduced as a site-related contaminant at a later date, with a shorter time period for migration relative to BTEX. The low detected concentrations of MTBE (below 15 µg/L) indicates that MTBE poses little risk at the site.

2.5 Naphthalene in Groundwater

Naphthalene was detected in three monitoring wells sampled in 1998 (ESMW-1A, ES-MW-5A, and MW-95. Similar to total BTEX and benzene, concentrations of naphthalene decreased in monitoring wells ESMW-1A (from 69.0 µg/L in July 1995 to 59.7 µg/L in September 1998) and MW-95 (from 25.4 µg/L in July 1995 to 20.8 µg/L in September 1998), and increased in monitoring well ESMW-5A (from 21.3 µg/L in

FIGURE 6
BENZENE VERSUS TIME AT SELECTED MONITORING WELLS
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA



022/722450/kingsalmon/2.xls/BENZENE

July 1995 to 30.5 μg/L in September 1998). Naphthalene typically migrates at a slower rate than BTEX compounds in groundwater due to a relatively higher affinity for soil sorption (retardation). Despite a slower migration rate for naphthalene, trends in concentrations of naphthalene mimic those for BTEX.

2.6 Tracer Compounds in Groundwater

TMBs and tetramethylbenzenes (TEMBs) were analyzed as tracer compounds in July 1995. TMBs were also analyzed in September 1994 and September 1998. These fuel constituents are recalcitrant to biodegradation under anaerobic conditions, and can be used as conservative tracers to calculate BTEX biodegradation rates under such conditions (Parsons ES, 1996). Concentrations of TMBs and TEMBs are summarized in Table 4 for reference. BTEX biodegradation rates were not calculated for 1998 data.

2.7 Inorganic Chemistry and Geochemical Indicators of Biodegradation

As discussed in the TS, microorganisms obtain energy for cell production and maintenance by facilitating thermodynamically advantageous reduction-oxidation (redox) reactions involving the transfer of electrons from electron donors to available electron acceptors. This results in the oxidation of the electron donor and the reduction of the electron acceptor. Electron donors at the KSA study area are natural organic carbon and fuel hydrocarbon compounds. Fuel hydrocarbons are completely degraded or detoxified if they are utilized as the primary electron donor for microbial metabolism (Bouwer, 1992).

Electron acceptors are elements or compounds that occur in relatively oxidized states and include oxygen, nitrate, ferric iron, sulfate, and CO_2. Microorganisms preferentially utilize electron acceptors while metabolizing fuel hydrocarbons (Bouwer, 1992). DO is utilized first as the prime electron acceptor. After the DO is consumed, anaerobic microorganisms use electron acceptors in the following order of preference: nitrate, ferric iron, sulfate, and CO_2. Anaerobic destruction of the BTEX compounds is associated with the accumulation of fatty acids, production of methane, solubilization of iron (ferrous iron) and manganese, and reduction of nitrate and sulfate (Cozzarelli *et al.*, 1990; Wilson *et al.*, 1990).

In the TS it was suggested that biodegradation of fuel hydrocarbons is occurring at the site via aerobic respiration and the anaerobic processes of denitrification and ferric iron reduction. Geochemical parameters for site groundwater are discussed below. Table 5 summarizes the geochemical parameters analyzed during the September 1994, July 1995, and September 1998 sampling events.

Dissolved Oxygen

DO concentrations were measured for the 7 wells sampled in September 1998 (Table 5). DO concentrations ranged from 0.4 to 9.0 milligrams per liter (mg/L) in September 1994, from 0.3 to 10.4 mg/L in July 1995, and from 0.9 to 10.0 mg/L in September 1998. Isopleths from September 1994, July 1995, and September 1998 can be seen on Figure 7. DO is considered to be an important electron acceptor at this site, due to high DO concentrations in groundwater at background monitoring points and depleted DO concentrations in source area wells. Because DO is recharged in the shallow

TABLE 4
TRACER COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Sample Location	Date	1,3,5-TMB[a] (µg/L)[c]	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	1,2,4,5-TEMB[b] (µg/L)	1,2,3,5-TEMB (µg/L)	1,2,3,4-TEMB (µg/L)
ESMW-1A	Sep-94	90.9	284	180	NA[d]	NA	NA
ESMW-1A	Jul-95	86.1	229	133	10.7	17.0	19.6
ESMW-1A	Sep-98	83.6	213	103	NA	NA	NA
ESMW-1B	Sep-94	65.7	144.0	81.4	NA	NA	NA
ESMW-1B	Jul-95	ND[e]	ND	ND	ND	ND	ND
ESMW-1B	Sep-98	ND	ND	ND	NA	NA	NA
ESMW-2A	Sep-94	ND	<1[f]	<1	NA	NA	NA
ESMW-2A	Jul-95	ND	ND	ND	ND	ND	ND
ESMW-2A	Sep-98	ND	ND	ND	NA	NA	NA
ESMW-2B	Sep-94	ND	ND	ND	NA	NA	NA
ESMW-2B	Jul-95	ND	ND	ND	ND	ND	ND
ESMW-3A	Sep-94	ND	<1	ND	NA	NA	NA
ESMW-3A	Jul-95	ND	ND	ND	ND	ND	ND
ESMW-3A	Sep-98	ND	ND	ND	NA	NA	NA
ESMW-3B	Sep-94	ND	<1	ND	NA	NA	NA
ESMW-4A	Sep-94	ND	ND	ND	NA	NA	NA
ESMW-4A	Jul-95	ND	ND	ND	ND	ND	ND
ESMW-4A	Sep-98	ND	ND	ND	NA	NA	NA
ESMW-4B	Sep-94	ND	ND	ND	NA	NA	NA
ESMW-5A	Sep-94	56.5	115.0	91.9	NA	NA	NA
ESMW-5A	Jul-95	12.2	22.1	11.4	2.7	3.3	4.4
ESMW-5A	Sep-98	46.7	109.7	52.4	NA	NA	NA
ESMW-5B	Sep-94	ND	ND	ND	NA	NA	NA
ESMW-5B	Jul-95	ND	ND	ND	ND	ND	ND
ESMW-6B	Sep-94	ND	ND	ND	NA	NA	NA
ESMW-6B	Jul-95	ND	ND	ND	ND	ND	ND
ESMW-7A	Apr-00	ND	ND	ND	NA	NA	NA
ESMW-7B	Sep-94	ND	ND	ND	NA	NA	NA
FT01-FD9	Sep-94	187.0	556.0	209.0	26.8	42.7	60.2
FT01-FD8	Apr-00	ND	ND	ND	ND	ND	ND
MW-92	Sep-94	ND	ND	ND	NA	NA	NA
MW-92	Jul-95	ND	ND	ND	ND	ND	ND
MW-93	Sep-94	ND	ND	ND	NA	NA	NA
MW-93	Jul-95	ND	ND	ND	ND	ND	ND
MW-94	Sep-94	ND	ND	ND	NA	NA	NA
MW-94	Jul-95	ND	ND	ND	ND	ND	ND
MW-95	Sep-94	9.4	25.0	14.6	NA	NA	NA
MW-95*	Sep-94	18.0	46.0	NA	NA	NA	NA
MW-95	Jul-95	33.2	75.2	43.7	3.6	5.0	6.5

TABLE 4 (Continued)
TRACER COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Sample Location	Date	1,3,5-TMB[a] (µg/L)[c]	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	1,2,4,5-TEMB[b] (µg/L)	1,2,3,5-TEMB (µg/L)	1,2,3,4-TEMB (µg/L)
MW-95	Sep-98	26.6	58.0	30.2	NA	NA	NA
435	Sep-94	27.9	72.5	41.8	NA	NA	NA
435	Jul-95	10.6	23.2	11.0	1.6	2.1	2.4
653*	Sep-94	290.0	410.0	NA	NA	NA	NA
653	Jul-95	95.7	272.0	146.0	17.7	27.2	41.5
460B	Sep-94	ND	ND	ND	NA	NA	NA
460B	Jul-95	ND	ND	ND	ND	ND	ND
462C	Sep-94	ND	ND	ND	NA	NA	NA
462C	Jul-95	ND	ND	ND	ND	ND	ND
GP-1	Jul-95	ND	ND	ND	ND	ND	ND
GP-2	Jul-95	<1	ND	ND	ND	ND	ND
GP-4	Jul-95	ND	1.0	ND	ND	ND	ND
GP-5	Jul-95	1.1	3.4	1.2	ND	ND	ND
GP-6	Jul-95	<1	1.1	ND	ND	ND	ND
GP-7	Jul-95	ND	ND	ND	ND	ND	ND
GP-8	Jul-95	ND	ND	ND	ND	ND	ND
GP-9	Jul-95	245.0	795.0	263.0	35.0	55.9	78.5
GP-10	Jul-95	ND	ND	ND	ND	ND	ND
SW1	Jul-95	20.5	24.7	16.3	8.0	10.7	15.6
SW2	Jul-95	ND	ND	ND	ND	ND	ND

[a] TMB = Trimethyl benzene.
[b] TEMB = Tetramethyl benzene.
[c] µg/L = micrograms per liter.
[d] NA = Not analyzed.
[e] ND = Not detected.
[f] <1 = less than limit of quantification.
* Reported by EMCON

TABLE 5
GEOCHEMICAL DATA FOR GROUNDWATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Temperature (°C)[b]	Dissolved Oxygen (mg/L)[c]	pH (su)[d]	Redox (mV)[e]	Chloride (mg/L)	Sulfate (mg/L)	Ferrous Iron (mg/L)	Soluble Manganese (mg/L)	Carbon Dioxide (mg/L)	Nitrate + Nitrite (mg/L)	Conductivity (µs/cm)[f]	Alkalinity (mg/L)	Methane (mg/L)	TOC[a] (mg/L)
ESMW-1A	9/94	6.7	0.9	6.50	63	2.93	3.43	2.5	0.9	140	0.09	300	132	NA[g]	27.30
ESMW-1A	7/95	4.9	1.4	6.81	35	2.07	1.39	3.0	NA	40	<0.05	161	81.6	<0.001	1.40
ESMW-1A	9/98	6.2	0.9	5.00	-90	2.82	5.00	5.0	NA	50	< 0.1	145	100	ND	11.90
ESMW-1B	9/94	5.4	2.1	6.80	202	3.43	<0.5	<0.05	<0.1	10	0.38	104	21	NA	1.60
ESMW-1B	7/95	4.6	2.0	6.85	150	3.47	3.71	<0.1	NA	25	0.25	134	68.0	<0.001	2.20
ESMW-1B	9/98	5.8	2.0	5.00	38	3.25	5.00	0.1	NA	20	0.50	135	80	ND	1.28
ESMW-2A	9/94	8.2	4.4	6.50	288	2.98	6.38	<0.05	NA	NA	2.69	195	67	0.002	6.50
ESMW-2A	7/95	4.6	5.1	6.72	240	2.42	4.80	<0.1	NA	35	1.38	117	54.4	<0.001	5.10
ESMW-2A	9/98	5.6	6.7	5.00	169	1.96	< 5.0	0.1	NA	20	0.58	126	60	ND	5.64
ESMW-2B	9/94	7.8	0.4	6.40	265	3.36	3.44	<0.05	NA	NA	0.11	141	58	0.063	2.60
ESMW-2B	7/95	5.5	0.4	6.50	230	3.04	3.13	<0.1	NA	50	0.38	113	54.4	<0.001	3.10
ESMW-3A	9/94	6.7	2.7	6.60	288	2.80	2.85	<0.05	0.1	NA	0.05	97	38	0.041	6.90
ESMW-3A	7/95	7.1	1.4	6.61	235	3.70	0.97	<0.1	NA	30	<0.05	100	47.6	0.126	2.40
ESMW-3A	9/98	5.8	3.2	4.90	132	2.44	5.00	0.1	NA	25	0.27	102	50	ND	4.29
ESMW-3B	9/94	5.9	1.0	6.50	284	3.71	3.56	<0.05	<0.1	NA	0.55	106	44	<0.001	1.30
ESMW-4A	9/94	6.8	7.0	6.20	280	3.57	4.00	<0.05	<0.1	40	0.60	120	47	0.002	8.20
ESMW-4A	7/95	4.8	5.2	6.52	250	3.99	3.16	<0.1	NA	90	2.52	157	68.0	0.001	6.20
ESMW-4A	9/98	5.0	10.0	4.90	385	2.31	< 5.0	0.1	NA	20	0.61	89	45	ND	4.85
ESMW-4B	9/94	6.9	7.5	7.00	271	3.88	2.61	<0.05	<0.1	12	0.40	81	9	<0.001	2.10
ESMW-5A	9/94	7.4	3.3	6.80	254	2.96	3.21	<0.05	0.2	48	0.37	239	84	<0.001	5.70
ESMW-5A	7/95	8.0	1.4	6.73	230	3.59	2.33	<0.1	NA	45	<0.05	162	81.6	<0.001	3.10
ESMW-5A	9/98	7.3	1.3	5.20	44	2.73	5.00	0.8	NA	22	<.1	221	110	0.07	8.92
ESMW-5B	9/94	5.6	1.4	7.70	242	3.51	2.79	<0.05	<0.1	8	0.11	134	57	0.002	1.40
ESMW-5B	7/95	7.0	0.3	7.38	200	3.43	2.20	<0.1	NA	15	<0.05	146	74.8	0.001	1.20
ESMW-6B	9/94	7.3	4.0	6.40	297	3.50	3.53	<0.05	<0.1	24	0.23	109	40	<0.001	3.40
ESMW-6B	7/95	7.6	0.4	6.61	250	2.44	1.52	<0.1	NA	30	<0.05	87	54.4	0.074	2.00
ESMW-7A	9/94	5.9	9.0	6.30	266	4.51	5.26	<0.05	0.2	36	2.82	188	43	<0.001	2.70
ESMW-7B	9/94	5.0	0.7	6.50	262	3.35	1.30	<0.05	0.1	40	<0.05	133	55	0.186	1.90

TABLE 5 (Continued)
GEOCHEMICAL DATA FOR GROUNDWATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Temperature (°C)[b]	Dissolved Oxygen (mg/L)[c]	pH (su)[d]	Redox (mV)[e]	Chloride (mg/L)	Sulfate (mg/L)	Ferrous Iron (mg/L)	Soluble Manganese (mg/L)	Carbon Dioxide (mg/L)	Nitrate + Nitrite (mg/L)	Conductivity (µs/cm)[f]	Alkalinity (mg/L)	Methane (mg/L)	TOC[a] (mg/L)
FT01-FD9	7/95	4.5	0.5	6.92	-35	3.38	<0.5	5.0	NA	70	<0.05	323	177.0	<0.001	10.20
FT01-FD8	7/95	5.5	6.0	6.42	200	6.02	2.91	<0.1	NA	55	2.21	150	54.4	<0.001	2.20
MW-92	9/94	5.0	3.0	6.10	219	3.49	3.13	<0.05	<0.1	44	0.92	134	45	0.001	6.50
MW-92	7/95	4.3	2.6	6.58	220	2.81	3.61	<0.1	NA	35	1.07	104	47.6	<0.001	3.60
MW-93	9/94	6.1	6.6	6.10	220	2.71	2.97	<0.05	<0.1	40	0.34	80	24	0.004	4.30
MW-93	7/95	4.6	2.5	6.50	220	3.39	2.77	<0.1	NA	30	0.13	70	34.0	0.123	1.60
MW-94	9/94	9.0	6.9	6.40	207	2.10	0.85	<0.05	<0.1	17	<0.05	86	36	0.087	1.40
MW-94	7/95	5.7	0.8	6.92	125	2.51	1.61	<0.1	NA	20	<0.05	74	40.8	0.390	1.50
MW-95	9/94	5.9	0.7	6.60	55	3.07	1.96	1.2	0.4	32	0.06	141	58	0.060	4.50
MW-95	7/95	6.1	0.4	6.72	15	3.30	1.60	3.0	NA	35	<0.05	116	74.8	<0.001	5.00
MW-95	9/98	6.8	0.9	5.20	-89	3.68	1.62	3.0	NA	30	<0.1	185	85.0	0.060	NA
435	9/94	5.0	2.0	7.10	214	2.79	2.78	<0.05	0.5	10	<0.05	276	116	0.135	5.50
435	7/95	5.4	1.8	7.19	205	2.53	1.01	<0.1	NA	20	0.11	141	74.8	0.001	4.30
460B	9/94	7.2	2.5	6.50	240	2.90	6.91	<0.05	0.4	48	0.55	233	89	<0.001	5.80
460B	7/95	5.0	3.6	6.62	260	2.78	5.85	<0.1	NA	30	0.79	161	81.6	<0.001	5.30
462C	9/94	6.8	1.4	6.30	282	2.36	1.80	<0.05	<0.1	90	0.14	97	41	0.072	4.80
462C	7/95	10.0	1.0	6.91	145	2.65	0.94	<0.1	NA	35	0.13	78	40.8	0.045	2.60
653	7/95	5.4	2.9	6.95	65	3.17	2.90	5.0	NA	55	0.34	181	47.6	<0.001	4.80
GP-1	7/95	5.3	2.2	6.36	225	4.17	1.89	<0.1	NA	75	2.41	172	81.6	<0.001	1.80
GP-2	7/95	4.6	9.9	6.61	95	2.15	<0.5	<0.1	NA	25	1.41	75	40.8	<0.001	1.50
GP-3	7/95	4.4	5.8	6.83	165	3.19	1.67	<0.1	NA	25	0.80	120	54.4	<0.001	1.70
GP-4	7/95	6.1	10.4	6.72	200	3.77	1.29	<0.1	NA	30	1.05	107	40.8	<0.001	1.80
GP-5	7/95	NA	NA	6.45	155	3.81	3.01	<0.1	NA	30	0.89	89	40.8	<0.001	3.20
GP-6	7/95	4.9	0.8	7.02	90	3.53	3.03	<0.1	NA	15	2.31	161	61.2	0.025	1.90
GP-7	7/95	2.5	0.7	6.37	145	4.27	4.00	2.5	NA	70	2.09	184	74.8	0.032	3.40
GP-8	7/95	5.5	0.0	6.46	100	2.31	1.77	<0.1	NA	30	2.02	93	27.2	<0.001	1.50
GP-9	7/95	5.9	0.5	6.78	-65	3.27	3.49	15.0	NA	105	<0.05	415	23.1	<0.001	12.30
GP-10	7/95	5.1	0.4	6.33	240	3.27	3.51	<0.1	NA	90	1.66	204	102.0	<0.001	6.80

TABLE 5 (Continued)
GEOCHEMICAL DATA FOR GROUNDWATER
FIRE TRAINING AREA 1 (FT01)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Temperature (°C)[b/]	Dissolved Oxygen (mg/L)[c/]	pH (su)[d/]	Redox (mV)[e/]	Chloride (mg/L)	Sulfate (mg/L)	Ferrous Iron (mg/L)	Soluble Manganese (mg/L)	Carbon Dioxide (mg/L)	Nitrate + Nitrite (mg/L)	Conductivity (µs/cm)[f/]	Alkalinity (mg/L)	Methane (mg/L)	TOC[a/] (mg/L)

[a/] TOC = Total organic carbon.
[b/] °C = Degrees Celsius.
[c/] mg/L = Milligrams per liter.
[d/] su = Standard pH units.
[e/] mV = Millivolts.
[f/] µs/cm = Microseimens per centimeter.
[g/] NA = Not analyzed.

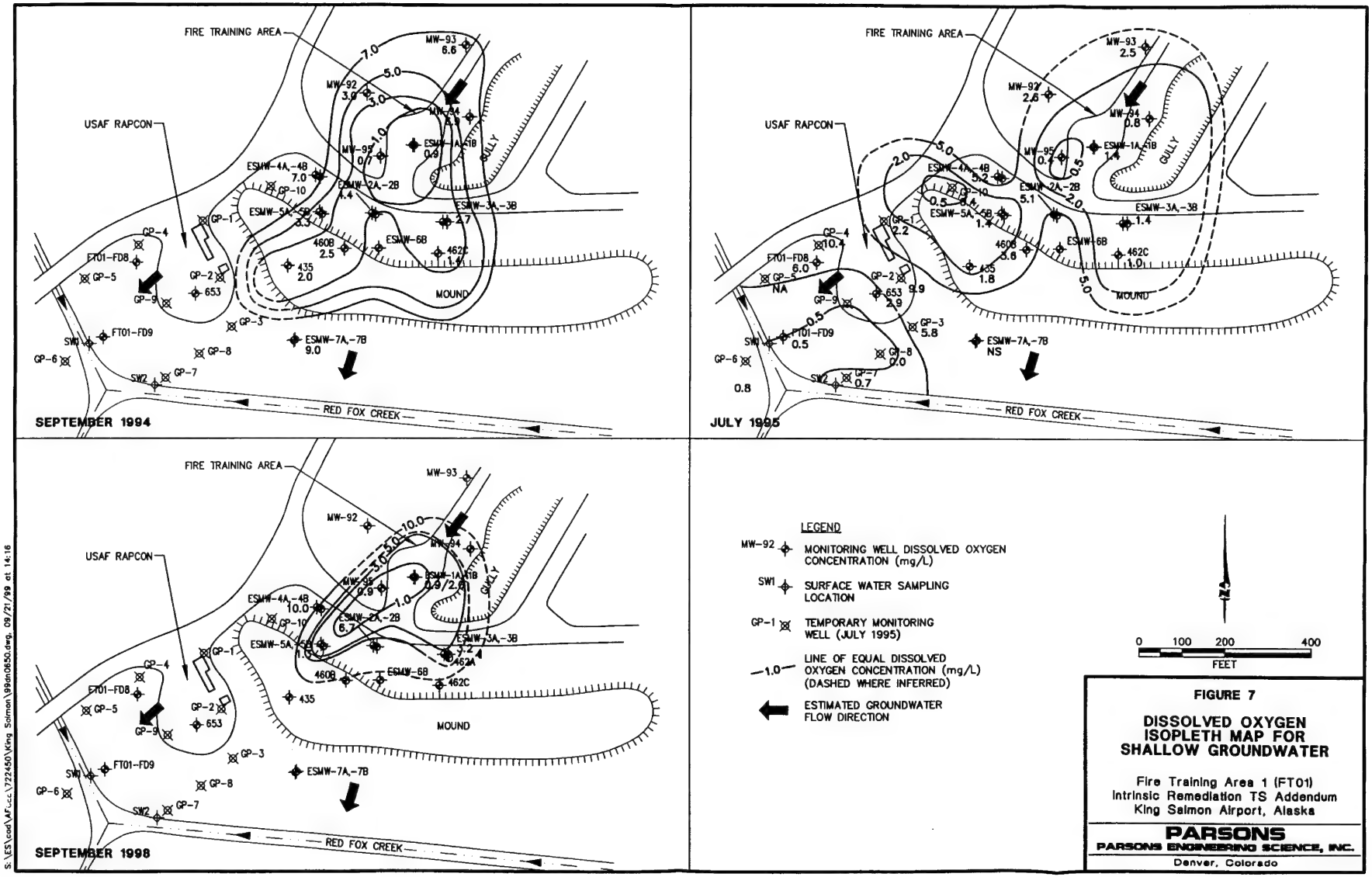


FIGURE 7

DISSOLVED OXYGEN ISOPLETH MAP FOR SHALLOW GROUNDWATER

Fire Training Area 1 (FT01)
Intrinsic Remediation TS Addendum
King Salmon Airport, Alaska

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groundwater through infiltration of precipitation, small, seasonal contributions to the degradation of fuel constituents through aerobic respiration can be expected, in addition to the normal recharge of DO from upgradient groundwater flow.

Nitrate+Nitrite

Nitrate+nitrite (as nitrogen) concentrations measured during the September 1998 sampling event were below detection limits in 3 of the 7 wells sampled (Table 5). September 1998 results ranged from 0.27 to 0.61 mg/L, showing a relative decrease in concentration from July 1995 data (0.11 to 2.52 mg/L).

As shown on Figure 8, nitrate concentrations were generally reduced in areas coinciding with high concentrations of dissolved BTEX. This relationship provides evidence that BTEX biodegradation continues through the microbially mediated process of denitrification.

Ferrous Iron

Ferrous iron (Fe^{2+}) is a byproduct of the anaerobic biodegradation process of ferric iron (Fe^{3+}) reduction. Accumulation of ferrous iron in groundwater indicates that this microbially assisted process is or has occurred recently. Ferrous iron concentrations were measured at the site and are presented in Table 5. Ferrous iron concentration contour maps for September 1994, July 1995, and September 1998 are shown on Figure 9.

Comparison of Figures 3 and 9 shows that areas with elevated total BTEX concentrations also have elevated concentrations of ferrous iron. Elevated ferrous iron concentrations were observed in the source area at the fire training area for all three sampling events. Concentrations of ferrous iron measured at the site during September 1998 range from 0.1 mg/L to 5.0 mg/L. Ferrous iron concentrations from 1995 to 1998 are similar, with slight increases at monitoring wells ESMW-1A (2.5 mg/L in 1995, to 3.0 mg/L in 1996 and 5.0 mg/L in 1998) and ESMW-5A (<0.05 mg/L in 1995, to <0.1 mg/L in 1996 and 0.8 mg/L in 1998). These wells are located at the BTEX source area and along the BTEX plume axis, respectively. A decrease in BTEX concentrations in 1998 was observed at source are well ESMW-1A, while an increase in BTEX concentration was noted downgradient at well ESMW-5A. This suggests that the area of iron reduction has expanded down the plume axis along with increasing BTEX concentrations, perhaps as a result of a migrating slug of dissolved BTEX.

Evidence suggests that the reduction of ferric iron to ferrous iron cannot proceed without microbial mediation (Lovley and Phillips, 1988; Lovley *et al.*, 1991; Chapelle, 1993); therefore, presence of ferrous iron strongly suggests that ferric iron is being used as an electron acceptor at the site. Furthermore, the coincident ferrous iron and BTEX plumes indicate that the reduction of ferric iron to ferrous iron is occurring during biodegradation of BTEX compounds.

Sulfate

Sulfate concentrations were measured at 5 of the 7 wells sampled during September 1998 and are presented in Table 5. Concentrations of sulfate measured at the site during September 1998 range from 1.62 mg/L to 5.0 mg/L. Concentrations ranged

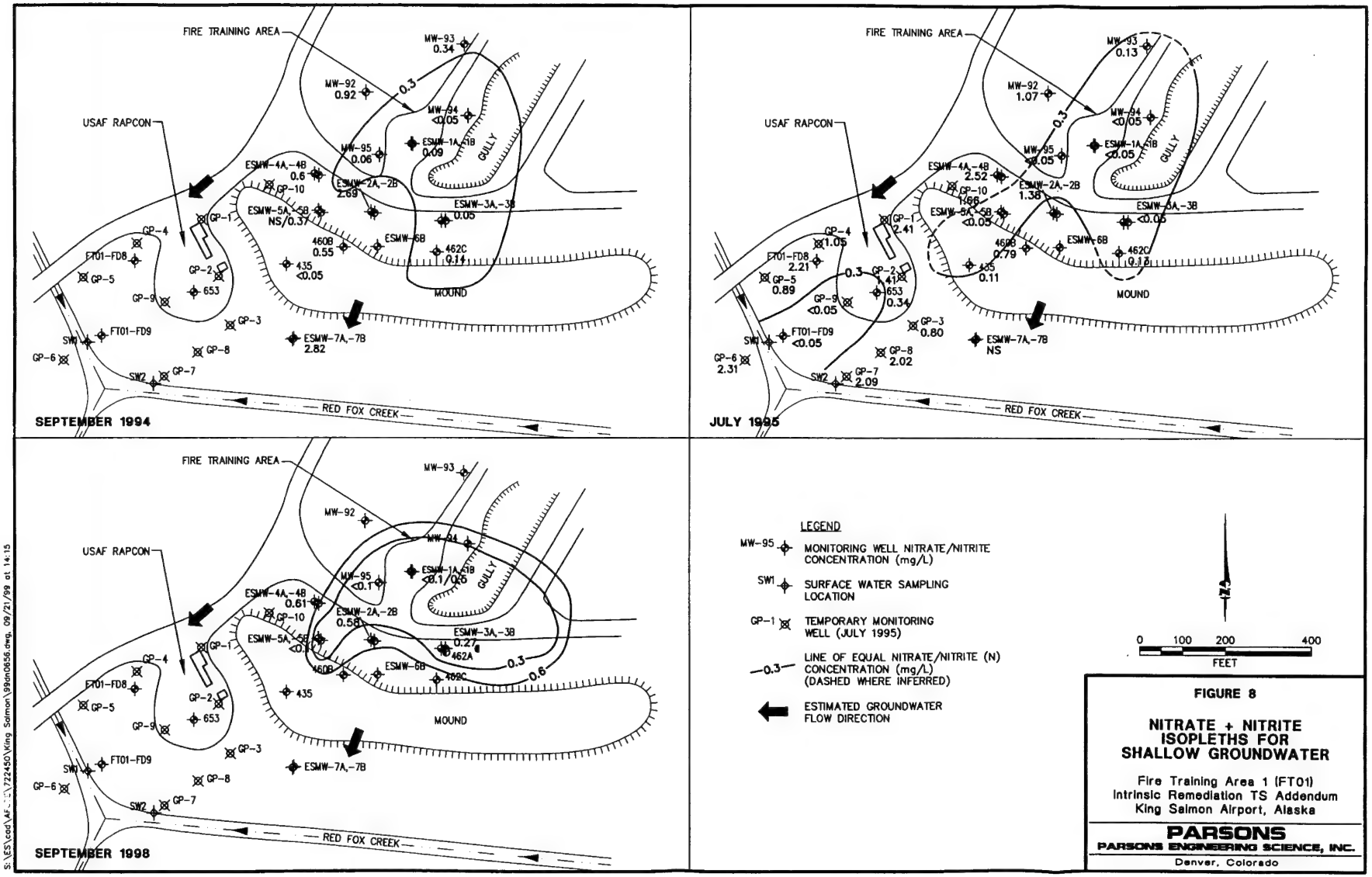

FIGURE 8

NITRATE + NITRITE ISOPLETHS FOR SHALLOW GROUNDWATER

Fire Training Area 1 (FT01)
Intrinsic Remediation TS Addendum
King Salmon Airport, Alaska

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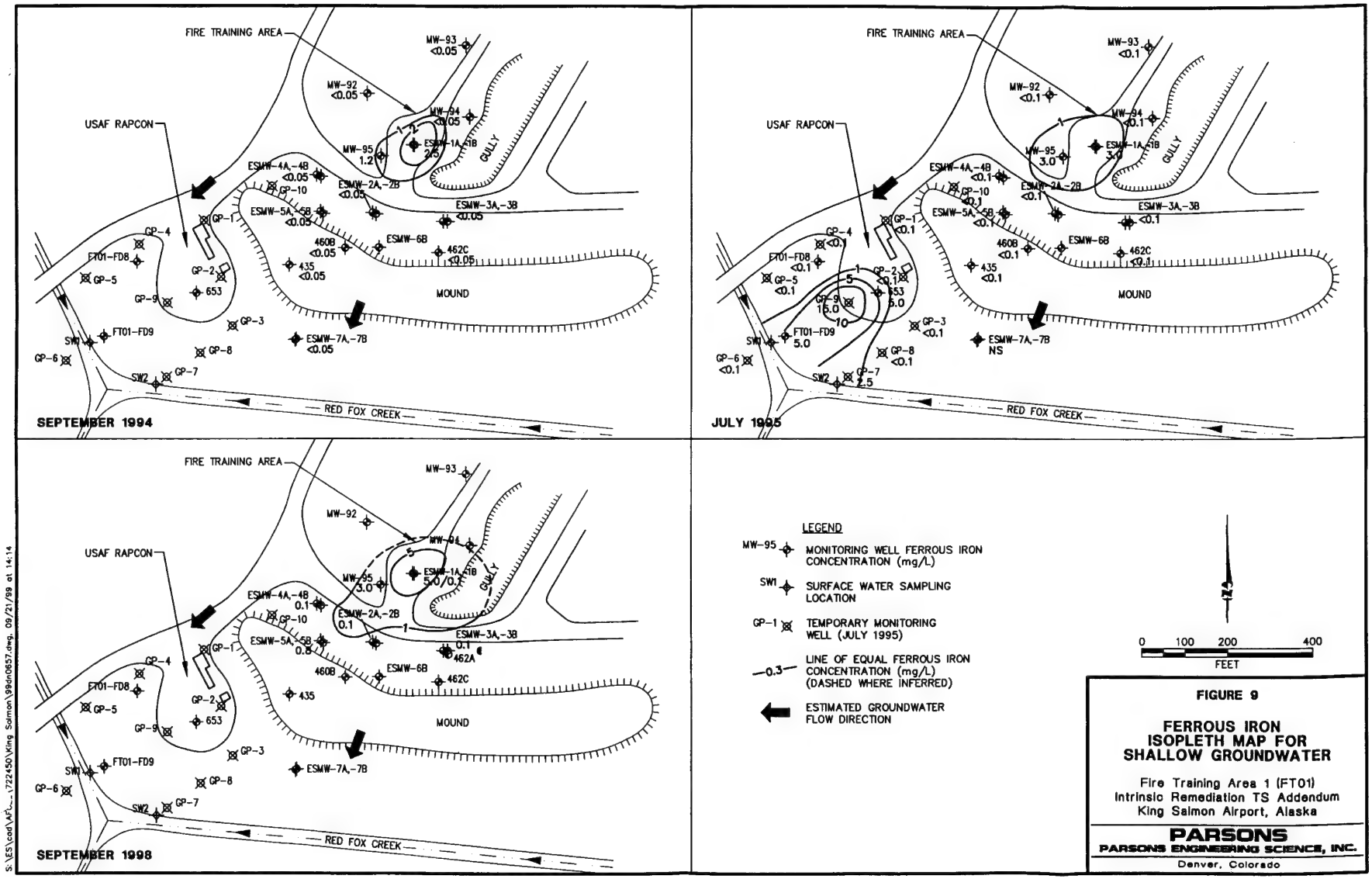

FIGURE 9

FERROUS IRON ISOPLETH MAP FOR SHALLOW GROUNDWATER

Fire Training Area 1 (FT01)
Intrinsic Remediation TS Addendum
King Salmon Airport, Alaska

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from <0.5 to 6.91 mg/L in September 1994, and from <0.5 to 5.85 mg/L in July 1995. The distribution of sulfate concentrations in the study area did not reflect a clear inverse relationship of reduced sulfate concentrations with increased BTEX concentrations. Based on the lack of a definitive trend of sulfate reduction for all three sampling events, sulfate is not considered to be an important electron acceptor at the fire training area.

Methane

During methanogenesis, an anaerobic biodegradation process, CO_2 (or acetate) is used as an electron acceptor and methane is produced. The presence of methane in groundwater is indicative of strongly reducing conditions and microbial degradation of fuel hydrocarbons. Methane concentrations were measured in groundwater in September 1994, July 1995, and September 1998 and listed in Table 5. Methane concentrations ranged from <0.001 mg/L to 0.156 mg/L in September 1994, and from <0.001 mg/L to 0.390 mg/L in July 1995. Methane and was only detected in 2 of the 7 sampled wells in September 1998 (0.07 mg/L in ESMW-5A and 0.060 mg/L in MW-95).

Methane concentrations across the study area were low and not distributed in a clear pattern. Based on the low methane concentrations in groundwater and the absence of definitive trends in methane production, methanogenesis is not considered to be an important anaerobic biodegradation process at the study area.

Oxidation Reduction Potential

ORP, a measure of the relative tendency of a solution to accept or transfer electrons, was measured at 7 wells sampled during September 1998. The dominant electron acceptor being reduced by microbes during BTEX oxidation is related to the ORP of the groundwater. ORPs measured at the site are summarized in Table 5. Concentration isopleth maps of ORP measured at the site in September 1994, July 1995 and September 1998 are presented on Figure 10. The ORPs measured in September 1998 at the site range from -90 millivolts (mV) to 385 mV.

Comparison of Figures 3 and 10 indicates that areas with low ORP coincide with areas characterized by high dissolved BTEX concentrations. Comparison of ORP values measured in September 1994, July 1995 and September 1998 (Figure 10 and Table 5) suggests that the ORP of groundwater at the site may be decreasing. In all sampling events, the redox potentials measured at Site FT01 were elevated above the theoretical redox potential required for iron reducing processes (Norris *et al.*, 1994), although limited iron-reducing processes observed through ferrous iron production were observed at the fire training area. This discrepancy is a common problem associated with measuring oxidizing potential using field instruments. Therefore, additional ORP data are required to assess whether this is an actual trend, or a result of sampling methods or techniques.

Alkalinity

Alkalinity is a measure of the ability of water to buffer changes in pH. Alkalinity can be used as an indicator of biodegradation of BTEX. Biodegradation of BTEX produces carbon dioxide which, when mixed with water in the proper conditions,

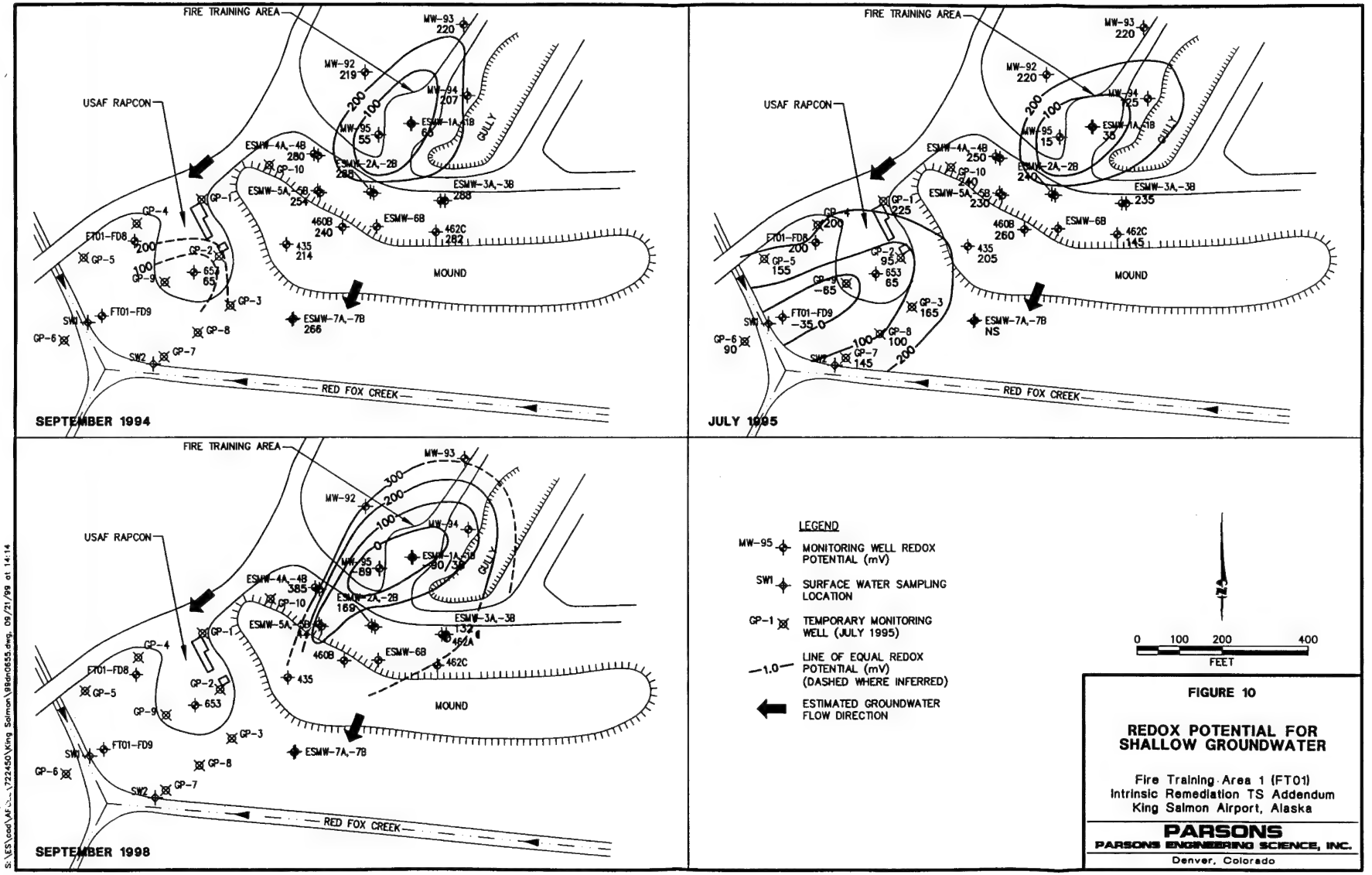

FIGURE 10

REDOX POTENTIAL FOR SHALLOW GROUNDWATER

Fire Training Area 1 (FT01)
Intrinsic Remediation TS Addendum
King Salmon Airport, Alaska

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produces carbonic acid. In aquifers that have carbonate minerals as part of the matrix, carbonic acid dissolves these minerals, increasing the alkalinity of the groundwater. Therefore, an increase in alkalinity can be observed in areas of active intrinsic bioremediation of BTEX. Total alkalinity (measured as calcium carbonate [$CaCO_3$]) of groundwater samples collected at the site in September 1994, July 1995, and September 1998 is summarized in Table 5.

Of the 7 wells sampled for alkalinity in September 1998, 6 wells increased in alkalinity concentration since July 1995, and only 1 decreased. The increase in alkalinity concentrations corresponds to a increase in ferrous iron concentrations and a decrease in BTEX concentrations. Therefore, alkalinity data support the continued occurrence of BTEX biodegradation at the site.

3.0 SUMMARY AND CONCLUSIONS

Without further remediation of residual phase LNAPL, natural attenuation is the only process acting to control the BTEX groundwater plume at Site FT01. The downgradient extent of the BTEX plume was not delineated in 1998. BTEX concentrations in monitoring wells near the source area (ESMW-1A and MW-95) decreased significantly between 1995 and 1998. BTEX concentrations at peripheral well locations ESMW-2A, ESMW-3A, and ESMW-4A also decreased, from low levels in 1995 to below detection (less than 1 µg/L) in 1998. However, BTEX concentrations at downgradient location ESMW-5A, along the approximate axis of the plume, increased significantly. BTEX concentrations observed in a deeper interval of the plume at well location ESMW-1B remained relatively stable at low concentrations (less than 3 µg/L) from July 1995 to September 1998.

The decrease in source area BTEX concentrations from 1995 to 1998 was accompanied by a simultaneous increase in downgradient BTEX concentrations at well ESMW-5A, possibly as the result of altered leaching conditions during source area excavation. Peripheral LNAPL sources may have been disturbed and remobilized at the groundwater interface during source excavation. This may have resulted in a temporary increase in leaching rates, thereby causing a slug of BTEX contamination to migrate from the source area. As the groundwater BTEX slug migrates, disperses, and degrades along the plume axis, the plume should stabilize in a steady-state configuration.

Because groundwater BTEX concentrations have steadily decreased in the source area since July 1995, it appears that source removal in 1995 has effectively reduced BTEX mass flux to groundwater. Although BTEX concentrations increased in the downgradient portion of the plume at well ESMW-5A, the decrease in BTEX concentrations at wells ESMW-1A, MW-95, ESMW-2A, ESMW-3A, and ESMW-4A suggest that biodegradation continues to limit plume expansion.

Geochemical data strongly suggest that biodegradation of fuel hydrocarbons continues at the site via aerobic respiration, denitrification, and iron reduction. The observed reductions in groundwater BTEX concentrations are historic evidence of plume attenuation and the receding risk of the groundwater plume associated with Site FT01. The BTEX plume in the vicinity of the source area and along the plume axis is

still largely anaerobic. Aerobic respiration and the anaerobic biodegradation processes of denitrification and iron reduction appear to be the predominant destructive attenuation mechanisms. An increase in BTEX concentrations in the downgradient portion of the plume (ESMW-5A) may be offset by increasing microbial activity at this location as evidenced by an increase in ferrous iron concentration.

BTEX concentrations near the source area (ESMW-1A and MW-95) are decreasing, and this will eventually cause the plume extent to diminish. Continued long-term monitoring (LTM) is recommended to monitor the evolution of the plume and to continue to evaluate the effectiveness of source reduction activities. Future LTM events should include sampling of downgradient monitoring wells 460B, 435, and ESMW-7A to delineate the downgradient extent of the BTEX plume. Future LTM for Site FT01 should also include well 653 and any future wells (as recommended in Section 7 of the TS [Parsons ES, 1996]) that would aid in differentiating the downgradient extent of the Site FT01 BTEX plume from commingling with the RAPCON Site BTEX plume (Figure 3).

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ATTACHMENT A

ANALYTICAL RESULTS
SEPTEMBER 1998

MANTECH

Ref: 98-MB12
Contract# 68-C-98-138
September 18, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: Dr. D. Fine

Dear Don:

Please find attached the analytical results for King Salmon AFB, AK, Service Request SF-0-13 requesting the analysis of monitoring well samples to be analyzed for MTBE, benzene, toluene, ethylbenzene, p-, m-, and o-xylene, 1,3,5-, 1,2,4-, and 1,2,3-trimethylbenzene, naphthalene and total fuel carbon. We received your 16 samples September 10, 1998 in capped, lead lined 40 mL VOA vials. The samples were analyzed on September 15 and 16, 1998. Samples were stored at 4°C until analyzed. Please note: sample ESMW-8A was diluted 1:10 with boiled milli-Q water. All samples were acquired and processed using the Millennium data system. A 5 point (1-1000 ppb) external calibration curve was used to determine the concentration for all compounds.

RSKSOP-133 "Simultaneous Analysis of Aromatics and Total Fuel Carbon by Dual Column/Dual Detector Gas Chromatography in Ground Water Samples" was used for these analyses. Autosampling was performed using a Dynatech-Precision autosampler in-line with a Tekmar LSC 2000 sample concentrator.

Sincerely,

Mark Blankenship

Mark Blankenship

xc: R.L. Cosby
G.B. Smith
J.L. Seeley

Pri [redacted])/19/98 SF-0-13 KING SALMON, AK

A [redacted] or Dr.Kampbell

Units = ng/ml [redacted] m. Blankenship

SAMPLE NAME	MTBE	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	NAPHTHALENE	FUEL CARBON
GC LAB BLANK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QC, OBSERVED, 20PPB	18.3	19.4	19.1	18.3	19.3	19.0	19.1	19.2	19.5	18.1	NA	NA
QC, TRUE VALUE, 20PPB	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	NA	NA
ESMW-1A	13.7	75.2	ND	275.8	306.0	961.4	470.0	83.6	212.8	102.9	59.7	2624
ESMW-1A LAB DUPLICATE	11.4	71.9	ND	251.7	284.2	888.2	441.2	79.0	201.0	97.4	56.7	2426
ESMW-1B	ND	ND	1.8	ND	ND	1.1	ND	ND	ND	ND	ND	3.0
ESMW-2A	ND	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
100 PPB STD	91.2	92.0	94.0	97.9	97.5	97.1	95.2	98.6	96.5	94.6	90.1	NA
ESMW-3A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ESMW-4A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ESMW-5A	13.9	418.8	3.4	99.8	147.7	271.2	180.6	46.7	109.7	52.4	30.5	1574
ESMW-8A	11.0	169.4	4900	405.0	280.2	753.9	6.11.39	112.9	331.9	250.7	184.1	9393
ESMW-8B	ND	ND	3.1	BLQ	BLQ	1.2	1.2	1.1	1.2	1.4	BLQ	31.0
ESMW-15A	3.8	BLQ	1.5	44.4	57.6	ND	1.5	13.5	ND	13.9	82.2	609.0
ESMW-15B	ND	BLQ	BLQ	8.5	9.4	BLQ	2.1	1.9	ND	13.4	17.1	263.0
MW-51	154.1	2.5	72.1	112.2	139.0	115.6	18.2	90.8	76.7	29.5	134.9	1609
MW-88	1.6	ND	BLQ	1.9	4.1	2.1	3.3	6.0	6.6	11.0	BLQ	221.0
MW-95	ND	68.3	611.2	63.6	84.2	221.1	121.8	26.6	58.0	30.2	20.8	1338.0
10 PPB STD	8.9	8.8	9.0	8.8	8.8	8.7	8.9	8.7	8.6	8.8	9.0	NA
MW-500	2.4	1.3	4.3	44.7	79.7	62.8	54.2	100.6	156.4	124.2	63.5	1806
WP-1A	2.4	23.1	1.6	50.5	69.1	76.7	37.7	34.3	106.9	77.9	56.8	1032
WP-1B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WP-1B LAB DUPLICATE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = None Detected; BLQ = Below Limit of Quantitation, 1ppb; NA = Not Analyzed

MANTECH

September 23, 1998
Ref: 98-LP27/lp
Contract # 68-C-98-138

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74821-1198

THRU: D.D. Fine DDF ine

Dear Don:

Attached are inorganic results for a set of 16 samples from King Salmon AFB, Alaska, submitted to MERSC under Service Request # SF-0-13. The samples were received September 10 and were analyzed September 11, 1998. The methods used for these samples were Lachat FIA methods 10-107-06-1-A for ammonia and 10-107-04-2-A for nitrate + nitrite and Waters capillary electrophoresis method N-601 for chloride and sulfate.

Quality assurance measures performed on this set of samples included spikes, duplicates, known AQC samples and blanks.

If you have any questions concerning this data, please feel free to contact me.

Sincerely,

Lynda Pennington

Lynda Pennington

xc: R.L. Cosby
J.L. Seeley
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Center, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 580-436-8660 FAX 580-436-8501

King Salmon AFB, Alaska
SF-0-13
Don Kampbell

SAMPLE	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
ESMW-1A	<.1	<.1	2.82	2.17
ESMW-1B	0.50	<.1	3.25	2.52
ESMW-2A	0.58	<.1	1.96	5.10
ESMW-3A	0.27	<.1	2.44	4.06
ESMW-4A	0.61	<.1	2.31	3.22
ESMW-5A	<.1	<.1	2.73	1.40
ESMW-5A dup	~~~	<.1	2.69	1.39
ESMW-8A	<.1	0.11	2.68	0.20
ESMW-8B	<.1	0.62	2.79	1.46
ESMW-15A	<.1	0.25	4.45	0.35
ESMW-15B	<.1	<.1	5.08	0.33
ESMW-15B	<.1	<.1	~~~	~~~
MW-51	0.46	<.1	2.71	1.95
MW-88	<.1	<.1	3.76	6.23
MW-95	<.1	0.20	3.68	1.62
MW-500	<.1	0.26	3.33	1.70
WP-1A	<.1	<.1	4.75	0.97
WP-1A dup	<.1	<.1	4.73	0.95
WP-1B	0.35	0.31	3.56	2.46
Blank	<.1	<.1	<.5	<.5
WPO39	1.04	0.79	11.0	57.0
WPO39 T.V.	1.10	0.84	10.8	58.0
Spike Recovery	99%	100%	100%	99%

MANTECH

Ref: 98JAD18

Contract # 68-C-98-138

September 22, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: Dr. Dennis Fine DF

Dear Don:

As requested in Service Request # SF-0-13, headspace GC/MS analysis of 15 King Salmon water samples for chlorinated volatile organics was completed. The samples were received of September 10, 1998 and analyzed on September 16, 1998. (RSKSOP-148 (Determination of Volatile Organic Compounds in Water by Automated Headspace Gas Chromatography/Mass Spectrometry (Saturn II Ion Trap Detector) was used for this analysis.

An internal standard calibration method was established for the 15 compounds. The standard curves were prepared from 1.0 to 5000 ppb. The lower calibration limits were 1.0 ppb.

If you should have any questions, please feel free to contact me.

Sincerely,

John Allen Daniel

John Allen Daniel

xc: R.L. Cosby
G.B. Smith
J.L. Seeley JS

Table 1. Quantitation Report for C.O.R. # SF-0-13 from King Salmon.

Concentration = ppb

Compound	ESMW1A	ESMW1B	ESMW2A	ESMW3A	ESMW4A	ESMW5A	ESMW5A Field Dup	WP1A	WP1B	ESMW8B	ESMW15A
VINYL CHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	1.2	ND	ND	ND
C-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHLOROFORM	ND	ND	ND	ND	ND	ND	ND	---	ND	ND	ND
1,1,1-TRICHLOROETHANE	1.0	ND	---	ND	ND	---	---	ND	2.0	ND	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

	ESMW15B	MW51	MW88	MW95	MW95 Lab Dup	MW8A	QC0916A 20 ppb	QC0916B 200 ppb	QC0916C 20 ppb	QC0916F 200 ppb	BL0916A
VINYL CHLORIDE	ND	ND	ND	ND	ND	ND	18.2	178	19.8	185	ND
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	22.9	220	23.0	230	ND
T-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	20.1	197	19.7	205	ND
1,1-DICHLOROETHANE	ND	ND	---	ND	ND	ND	21.6	220	23.3	220	ND
C-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	21.1	218	22.0	214	ND
CHLOROFORM	ND	ND	1.8	ND	ND	ND	21.4	209	22.0	203	ND
1,1,1-TRICHLOROETHANE	ND	ND	2.7	---	---	ND	20.6	200	21.3	211	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	20.5	202	21.7	209	ND
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	21.8	231	21.9	215	ND
TRICHLOROETHENE	ND	ND	---	ND	ND	ND	18.7	185	19.4	186	ND
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	20.8	203	20.5	201	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	21.8	215	21.9	214	ND
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	21.8	206	21.7	212	ND
1,4-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	22.1	217	22.2	212	ND
1,2-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	22.6	218	22.6	219	ND

ND = None Detected --- = Below Calibration Limit(1.0 ppb) QC = Quality Control Std BL = Blank Dup = Duplicate

MANTECH

Ref: 98-AZ16
68-C-98-138

September 14, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: D. Fine

Dear Don:

As requested in Service Request #SF-0-13, gas analysis was performed for methane, ethylene, and ethane on samples from King Salmon Airport. The samples were received on September 10, 1998. The analyses were performed on September 11, 1998. These analyses were performed as per RSKSOP-194, and the calculations were done as per RSKSOP-175.

If you should have any questions, please feel free to contact me.

Sincerely,

Amy Zhao

xc: R.L. Cosby
G.B. Smith
J.L. Seeley

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Center, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 580-436-8660 FAX 580-436-8501

SF-0-13 King Salmon Airport **09/14/1998**

Sample	Methane	Ethylene	Ethane
100 ppm CH4	97.3	**	**
100 ppm C2H4	**	101.2	**
100 ppm C2H6	**	**	103.1
HP. Helium Blank	**	**	**
Lab Blank	**	**	**
ESMW-1A	**	**	**
ESMW-1B	**	**	**
ESMW-2A	**	**	**
ESMW-3A	**	**	**
ESMW-4A	**	**	**
ESMW-4A Lab DuP	**	**	**
ESMW-5A	0.07	**	**
ESMW-8A	0.64	*	0.004
ESMW-8B	0.13	**	**
ESMW-15A	3.35	**	**
ESMW-15B	0.01	**	**
ESMW-15B Field Dup	0.01	**	**
10,000 PPM CH4	1.05E+04	**	**
MW-51	0.02	**	**
MW-88	**	**	**
MW-95	0.06	**	**
MW-500	0.34	**	**
MW-1A	5.86	**	**
MW-1B	**	**	**
MW-1B Field Dup	**	**	**
10 PPM CH4	10.0	**	**
10 PPM C2H4	**	10.1	**
10 PPM C2H6	**	**	10.0
1000 PPM CH4	1.06E+03	**	**
Lower Limit of Quantitation	0.001	0.003	0.002

Units for the standards are parts per million.

** denotes None Detected.

MANAGEMENT TECHNOLOGY

Ref: 98-SH16
Contract # 68-C-98-138

September 16, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: D.D. Fine

Dear Don:

Attached are TOC results for a set of 16 King Salmon liquids submitted September 11, 1998 under Service Request #SF-0-13. Sample analysis was begun September 16, 1998 and completed September 16, 1998 using RSKSOP-102.

Blanks, duplicates, AQC samples were analyzed along with your samples, as appropriate, for quality control. If you have any questions concerning this data, please feel free to ask me.

Sincerely,

Sharon Hightower

Sharon Hightower

xc: R.L. Cosby
G.B. Smith
J.L. Seeley

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

KAMPBELL KING SALMON LIQUIDS SF-0-13

SAMPLE	MG/L TOC
ESMW-1A	11.9
ESMW-1B	1.28
ESMW-2A	5.64
ESMW-3A	4.29
ESMW-4A	4.85
ESMW-5A	8.92
ESMW-8A	56.0
ESMW-8B	2.89
ESMW-15B	8.24
WP-1A	17.6
DUP	17.8
WP39	77.0

WP39 std. t.v.=76.0+/-7.60

September 1-3, 1998 Hill AFB, Utah											
SAMPLE	TOC Water Level (feet)	pH	Redox (mV)	Conductivity (µS/cm)	D.O. (mg/L)	Temp. (°C)	Ferrous Iron (mg/L)	Alkalinity (mg/L)	Sulfate (mg/L)	H_2S (mg/L)	CO2 (mg/L)
LTM-3	16.90	7.12	-95.3	875	7.6	17.8	8	520	10	<0.1	65
LTM-4	22.56	7.36	-199	2080	0.38	18.5	2	1360	20	2.0	60
LTM-6	23.60	7.07	-96.5	1330	10.4	18.7	10	760	5	<0.1	60
LTM-7	8.58	7.24	150	1640	3.45	17.9	<0.1	600	10	<0.1	50
LTM-8	10.02	7.14	-59.5	1520	0.44	14.9	10	840	10	<0.1	55
LTM-9	11.28	7.21	109	1060	1.15	16.1	<0.1	660	10	<0.1	45
	Note: LTM-4 & LTM-6 were both low-yielding wells so no hydrogen analysis was done.										
September 4-9, 1998 King Salmon, Alaska											
SAMPLE	TOC Water Level (feet)	pH	Redox (mV)	Conductivity (µS/cm)	D.O. (mg/L)	Temp. (°C)	Ferrous Iron (mg/L)	Alkalinity (mg/L)	Sulfate (mg/L)	H_2S (mg/L)	CO2 (mg/L)
ESMW-1A	16.8	5.0	-90	145	0.85	6.2	5	100	5	<0.1	50
ESMW-1B	16.8	5.0	38	135	2.0	5.8	0.1	80	5	<0.1	20
ESMW-2A	18.2	5.0	169	126	6.7	5.6	0.1	60	<5	<0.1	20
ESMW-4A	16.1	4.9	385	88.8	10	5.0	0.1	45	<5	<0.1	20
MW-95	15.1	5.2	-89	185	0.9	6.8	3	85	10	<0.1	30
ESMW-5A	6.2	5.2	44	221	1.28	7.3	0.8	110	5	<0.1	22
ESMW-3A	16.9	4.9	132	102	3.2	5.8	0.1	50	5	<0.1	25
MW-51	11.5	5.1	-48	400	0.7	5.2	8	195	5	<0.1	96
MW-500	19.1	5.3	-71	380	1.4	4.5	20	220	5	<0.1	70
MW-501	14.2		"pumped dry" - no data								
MW-88[illegible]	14.4	5.0	24	276	2.0	6.0	5	120	<5	<0.1	45
WP-1A	4.8	5.1	-69	355	0.7	3.8	40	60	<5	<0.1	85
WP-1B	5.4	5.0	22	111	7.4	6.7	0.1	200	10	<0.1	10
ESMW-8A	12.3	5.2	-40	540	0.8	7.0	30	280	<5	<0.1	75
ESMW-8B	10.7	5.0	-11	108	0.9	5.8	0.1	60	<5	<0.1	15
ESMW-15A	16.1	5.3	-23	393	0.6	4.8	>50	200	<5	<0.1	***
ESMW-15B	16.1	5.5	-3	430	2.0	5.0	1.5	220	<5	<0.1	1.5
	*** = couldn't determine an endpoint for CO2 due to high concentration of ferrous iron.										